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LAKE AND POND MANAGEMENT

Field Manual

Massachusetts Department of Environmental Management

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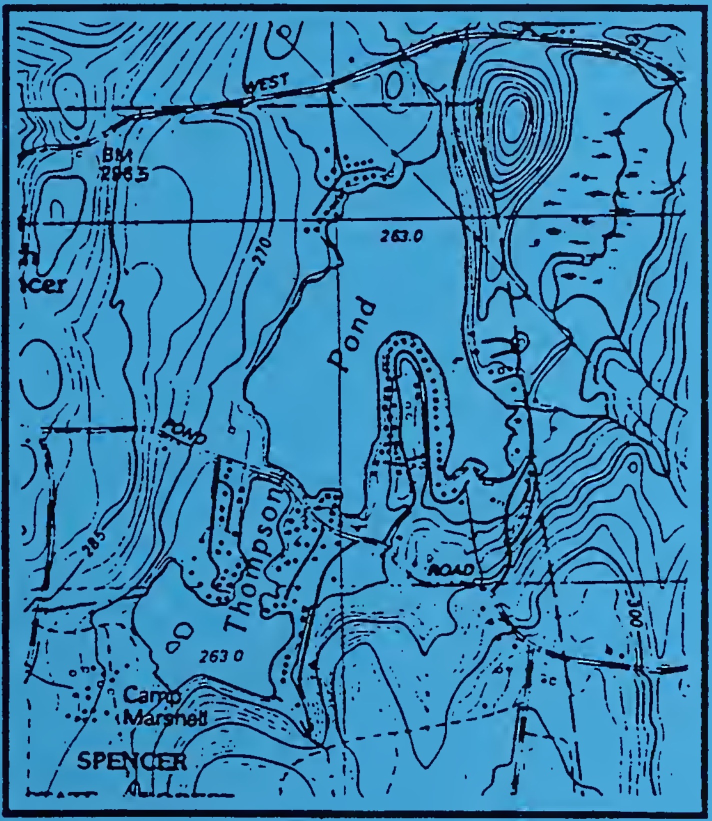

A Comprehensive Short Course in
Strategies to Preserve and Restore Lakes

1996 New England Lake Conference Edition

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INTRODUCTION

The following lakes assessment and management field manual is grounded in sciences, yet is focused on the practical problems facing DEM staff. This manual consists of materials relevant to lake and pond assessment and management, and includes written text and worksheets intended for DEM use.

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SECTION 1.

LAKE ASSESSMENT METHODOLOGY

LAKE ASSESSMENT METHODOLOGY

WHAT PARAMETERS SHOULD BE ANALYZED

See Section 1 of the coursebook for a description of lake functions.

When initially surveying a lake or pond the parameters or measurements for the baseline data should include information on the physical, chemical and biological components of the lake. Following a thorough analysis of the baseline data, further surveys can be designed to accommodate individual lake or pond characteristics and more effectively focus on the problem of concern. For lakes or ponds with no apparent problem, it is still useful to periodically monitor conditions to detect the symptoms of the changes (e.g., eutrophication) as early as possible.

When selecting parameters to measure or determine for a lake analysis, it is important to consider why they are being collected. There are numerous examples of extensive long-term monitoring data sets that have little utility because they measured the wrong parameters, switched parameters arbitrarily during the study, lack important additional information (e.g., flow measurements, weather conditions), have inappropriate or redundant sampling locations, or the timing of sampling was not coordinated with lake events (e.g., thermal stratification). Since the initial set of sampling parameters often becomes the template for subsequent samples, it should be designed carefully.

See page 3-21 through 3-33 for a discussion of diagnostic study methodologies.

The information necessary to diagnose a lake or pond's current condition and details of water quality monitoring are presented in Section 3 of the course manual. The reader is advised to refer to Section 3 of the course manual for the relevant information. Information about the type of equipment typically used for lake sampling is discussed below.

IMPORTANCE OF WATER QUALITY SAMPLING AND ANALYSIS FOR PROBLEM IDENTIFICATION, FEASIBILITY PLANNING, AND POLICY FORMATION

A manager of lakes and ponds often tries to reduce water-quality problems (e.g., low dissolved oxygen, insufficient water clarity) that are really symptoms of some underlying problem (e.g., excessive nutrient loading from the watershed). Generally, for solutions to be successfully chosen and implemented, the root cause of a problem must be correctly identified. Water quality sampling and analysis is an important step to identify and evaluate water quality problems.

By identifying the ultimate cause of a symptom, water quality sampling also aids in the assessment of alternative feasibility options. If the cause of the problem is excessive nutrients coming in from the watershed, for example, some sort of source control will generally alleviate the problem. However, if the source of the problem is nutrient-rich sediments already in the lake, as is the case with most instances of excessive macrophyte growth, it is often more cost-effective to deal with the symptom and ignore the root cause.

Establishing baselines and detecting trends are two other important goals of regular water quality sampling. Lakes undergo natural changes in water chemistry and biology from season to season and from year to year. Significant degradation or change can be detected only in relation to a base-line established by prior monitoring. Additionally, water quality monitoring may allow detection of subtle changes in water chemistry before they produce noticeable reductions of the aesthetic or biological resource value of the lake.

A monitoring program is also useful in for establishing policies regarding use of the lake and goals for its protection or remediation. Certain water qualities (e.g., very low clarity) are incompatible with certain uses (e.g., bathing); this can only be determined through water-quality monitoring. Moreover, data on current water quality are often necessary to spur political movement for lake protection or restoration, and these data are also necessary to gauge their success or failure.

BASIC DESCRIPTION OF WATER QUALITY PARAMETERS

What follows is a list of the physical-chemical parameters most often measured in lakes. A short description of the importance of each major parameter is also provided. An excellent and detailed discussion of the cost of sampling, optimal sampling density, and sampling costs can be found in Chapter 8 of Ryding and Rast (1989).

Secchi Disk Transparency

See page 1-11 and 1-12 of the coursebook for a discussion of bathymetry.

Use of a Secchi disk is a simple method to gauge water clarity. A black and white disk (the Secchi disk) is lowered into the water until the disk disappears. The depth of disappearance is the Secchi disk transparency; thus, high Secchi disk depths indicate high water clarity. Because one's ability to see through water depends on ambient light, Secchi disk measurements depend upon weather conditions and the time of day as well as on factors affecting water clarity. These factors include suspended solids, phytoplankton density, and concentration of some dissolved solids, especially dissolved organics.

Because turbidity, especially in deep stratified lakes, is primarily affected by phytoplankton biomass, Secchi disk depths can be used as an indicator of trophic status. Thus, mesotrophic lakes are those with readings from 3 to 6 meters, and eutrophic lakes generally have readings less than 3 meters. However, in lakes with heavy weed growth, Secchi-disk readings can be very high despite the obvious eutrophic nature of the water body. Conversely, in ponds stained by organic acids or cloudy with sediments, Secchi-disk readings can be very low despite minimal aquatic plant growth.

Temperature and Stratification

See page 1-16 through 1-21 of the coursebook for a discussion of lake stratification and mixing.

Temperature gradients are set up in lakes as upper layers of water are warmed by radiant energy from the sun and thermal energy from the air. Because the density of water decreases as water temperature rises above 40° C, colder water near the bottom tends to remain below warmer water near the surface, setting up a temperature-density gradient called stratification. (Swimmers should recognize this phenomenon; deeper waters tend to be much cooler than those near the surface). Stratification usually begins in early spring, intensifies in summer, and breaks down in the fall as sunlight wanes and air temperatures fall.

Wind tends to counteract the formation of stable temperature gradients by mixing and stirring the water column. However, if the wind is too weak or the density gradient too strong or too deep, wind-mixing will be unable to stir the entire water column. In this case, long-term stratification can occur, dividing the lake into a warm, upper layer—the epilimnion—and a cold, bottom layer—the hypolimnion. The zone of transition between the two strata is called the thermocline, or metalimnion. Lakes that remain stratified for periods longer than several months are said to undergo stable stratification.

Because more energy (i.e., higher wind velocity) is required to stir deeper columns of water, stratification tends to be more long-lived in deeper lakes compared to stratification in shallow lakes. Deep temperate lakes generally stratify from spring to fall, and mix completely during early spring and late fall when winds are strong and thermal-density gradients are weak. Shallow lakes and ponds, on the other hand, tend to mix more or less completely throughout the summer. They may become stratified for short periods, especially during warm, calm days, but this stratification soon breaks down as the epilimnion cools and/or the wind rises.

Stratification is important because physical, chemical, and biological processes behave quite differently in warm, sunlit epilimnia compared to these processes in cold, dark bottom waters. Consequently, the water column, which starts out essentially homogeneous during spring mixing, often becomes divided in the summer into two strata with very different chemical and biological characteristics. For example, while the epilimnion is usually nearly saturated with oxygen, dissolved oxygen tends to become depleted in bottom waters. If the hypolimnion becomes completely anoxic, game-fish that require cold water (e.g., trout and salmon) may be unable to survive in the lake. In addition, nutrient dynamics in anoxic waters differ from those in oxygenated waters. Oxygen-depletion promotes the release of phosphorus and certain metals (e.g., manganese and iron) from the sediments. The release of phosphorus may exacerbate eutrophication and impede efforts to redress excessive nutrient loadings.

Dissolved Oxygen

Dissolved oxygen may be the most critical lake chemistry parameter. During prolonged periods of low oxygen concentrations (less than about five milligrams per liter), cold-water fish (trout, salmon) may die of asphyxiation. Warm-water fish are generally more tolerant of oxygen depletion, surviving well until oxygen falls below 2 mg/l. Dissolved oxygen dynamics also greatly affect nutrient dynamics in lakes. The solubility of phosphorus increases significantly in the absence of oxygen; thus, anoxia can promote release of this vital nutrient from the sediments.

Oxygen concentrations in lakes are primarily affected by the physical processes of dissolution from the atmosphere, (called re-aeration) and by the biological processes of photosynthesis and respiration. During daylight hours, oxygen is produced by plants and phytoplankton in the euphotic zone, the upper layer in which light is adequate for photosynthesis. The depth of the euphotic zone can be approximated by multiplying the Secchi disk depth by three. Since surface waters can also become oxygenated by contact with the air, upper layers generally contain high amounts of dissolved oxygen. In contrast, dark bottom waters receive no oxygen from photosynthesis or from the atmosphere. Respiratory processes which consume oxygen predominate below the euphotic zone; thus, bottom waters often become anoxic.

The relationship between depth and oxygen dynamics demonstrates the importance of thermal stratification. In shallow lakes without stable stratification, mixing continuously brings bottom waters to the surface where the oxygen is replenished through re-aeration and photosynthesis. In deep lakes that undergo stable stratification, however, bottom waters stay well below the surface from spring to fall. Without access to atmospheric or photosynthetic oxygen to meet the needs of biological respiration, these bottom waters can become depleted in oxygen.

Bacteria

Since fecal contamination contains a number of pathogens that present risks to human health, bacteria that tend to occur in feces are used as a warning indicator of the presence of these fecal pathogens. However, the diagnostic bacteria themselves are not usually pathogenic; high bacteria levels do not in themselves pose any real health risk.

Three types of bacteria are generally measured in lakes and ponds: total coliform, fecal coliform, and fecal streptococci. Total coliform bacteria are probably the most widely used indicator group, even though they are probably the least reliable indicator of fecal pollution. Total coliform includes the fecal coliform bacteria which come from animal waste, but also includes some bacteria that naturally occur in soils. Therefore, high total coliform counts do not necessarily indicate a high degree of fecal contamination.

Fecal coliforms are that subset of the total coliform group that usually originate in fecal material. The primary species of the fecal coliform group is Escherichia coli, a normally non-pathogenic bacterium found in the guts of warm- blooded animals. Fecal streptococci are another group of bacteria found in the guts of warm-blooded animals. Different organisms generally have different ratios of fecal coliform to fecal streptococci, so the ratio of the two can be used to identify the source of the contamination.

ANIMAL SOURCE AND FC/FS RATIOS*

Human	4.4
Duck	0.6
Turkey	0.1
Chicken	0.4
Cow	0.2
Sheep	0.4

*Taken from Microbiological Methods for Monitoring the Environment: Water and Wastes. EPA-600/8-78-017. Edited by Robert Border and John Winter.

Because of the frequent co-incidence of these indicator bacterial groups and human pathogens, EPA has set standards for total coliform and fecal coliform concentrations in bathing beaches. The EPA limit for total coliform is 1000 organisms per 100 ml, while the limits for fecal coliform bacteria are that the geometric mean should be below 200 organisms per 100 ml, and 10% of all samples should not exceed 400 organisms per 100 ml. There are no standards set for fecal streptococci bacteria.

Phosphorus

See page 1-21 through 1-27 of the coursebook for a discussion of lake nutrient and chemical regimes.

According to what is called Liebig's "Law of the Minimum," the productivity of aquatic systems is controlled by the nutrient that is in lowest supply compared to the nutritional requirements of aquatic plants and algae. This nutrient, called the limiting nutrient, is the component that most often constrains plant growth.

In most freshwater systems, phosphorus is the most critical plant nutrient. Phosphorus is so important to the health of a lake that some lake classification schemes depend entirely on the in-lake phosphorus concentration (see Table 1). Generally, lakes with low concentrations of phosphorus tend to be clean and aesthetically pleasing, while the opposite is true of lakes with high concentrations of phosphorus.

TABLE 1

TROPHIC STATE CLASSIFICATION

Phosphorus Concentration (mg/liter)	Trophic State	Lake Use
<0.010	Oligotrophic	Suitable for water-based recreation and propagation of cold water fisheries, such as trout. Very high clarity and aesthetically pleasing.
0.010 - 0.020	Mesotrophic	Suitable for water-based recreation but often not for cold water fisheries. Clarity less than oligotrophic lake.
0.020 - 0.050	Eutrophic	Reduction in aesthetic properties diminishes enjoyment for body contact recreation. Generally very productive for warm water fisheries.
>0.050	Hyper-eutrophic	A typical "old aged" lake in advanced succession. Some fisheries, but high levels of sedimentation and algae or macrophyte growth may be diminishing open water surface area.

Source: K.H. Reckhow, M.N. Beaullac and J.T. Simpson, Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients, June 1980.

Assigning a trophic status to shallow and small lakes based solely on phosphorus values can be problematic for two reasons. First, trophic-state classifications are based on large, deep lakes that are primarily pelagic (deep, open water). Such a classification scheme may not apply to shallow lakes and ponds which are primarily littoral zone (shallow areas that support rooted vegetation). Most species of rooted aquatic vegetation can derive phosphorus from the sediments; hence, concentration of phosphorus in the water column may have little impact on the growth of these potential nuisance plants. Second, given the negative connotations associated with the colloquial definition of "eutrophic", classification as "eutrophic" can give misleading impressions about the health of a lake. One should note that the criterion for the mesotrophic-eutrophic border is 0.020 mg/l, but the EPA warning limit for phosphorus concentrations in standing water is 0.025 mg/l. Clearly, many eutrophic lakes are healthy and useful resources

Several forms of phosphorus are commonly measured: total phosphorus which included soluble phosphorus, inorganic phosphorus, and phosphorus bound in living and non-living organic matter. Since soluble phosphorus is constantly being absorbed by phytoplankton and bacteria and being released by living and non-living matter, samples for soluble phosphorus should either be filtered in the field or chilled and filtered immediately upon arrival at the laboratory.

Nitrogen

After phosphorus, nitrogen is the most important nutrient essential for plant growth in aquatic systems. Nitrogen commonly occurs in three forms in aquatic systems: nitrate, ammonia, and organic nitrogen. Four forms of nitrogen compounds are commonly measured in lakes and ponds: nitrate, nitrite, ammonia, and total Kjeldahl nitrogen (TKN). Using these values, total nitrogen can be calculated as the sum of the nitrogen in TKN, nitrate, and nitrite. Organic nitrogen, which is the nitrogen produced by animals and plants, can be calculated as the difference between the concentration of TKN and the concentration of ammonia nitrogen.

pH and Alkalinity

The pH of a lake is a measure of the acidity of the water. A pH of 7.0 is neutral. Values below 7.0 denote acidic waters, and values above 7.0 denote basic waters. Most healthy aquatic systems maintain a pH reading between 6.5 and 8 pH units. Fish cannot tolerate pH levels below 4 and above 11, and their growth and health will be affected by long-term exposure to waters less than 6.0 pH units and greater than 9.5 pH units (Boyd 1982).

The pH and alkalinity of an aquatic system are closely related. The alkalinity measured in a pond represents the water body's buffering capacity, or its acid neutralization capacity which is measured in mg/l of $CaCO_3$. Low levels of alkalinity suggest either that a lake has undergone acidification and/or that it is prone to acidification. If a lake's alkalinity is less than 20 mg/l $CaCO_3$, it can be considered "sensitive" to acidic precipitation.

Chloride and Conductivity

The primary natural sources of chloride are from the weathering of soils and rocks, and from wet and dry precipitation. The latter can be a particularly important source of chloride, especially in areas near the ocean from salt aerosols. Anthropogenic sources of chloride are roadway salts and waste-waters. Both can be a significant source of chloride to a lake.

Conductivity is the ability of a water sample to conduct electricity, and measures the presence of ions in solution. Since chloride is often the predominant ion in surface waters, conductivity values for water samples will often show similar patterns to concentrations of chloride.

Chloride and conductivity are generally used as measures of pollution from de-icing salts, and sometimes as measures of overall fertility.

Suspended Solids

Suspended solids are a measure of the amount of particulate matter that can be filtered out of the water. Suspended solids include living and non-living matter that may originate within the pond (autochthonous material) or outside the pond (allochthonous material). Autochthonous suspended solids are primarily phytoplankton or organic particles in some state of decay. Allochthonous particles may be a mixture of organic and non-organic particles that are washed or blown into the lake.

The concentration of suspended solids in tributary waters can be a useful indicator of sediment loads that can identify potential problems with excessive sedimentation. In contrast, the motley nature of the particles that make up suspended solids decreases its information value for in-lake samples. If the suspended solids are primarily mineral solids washed into the watershed, high levels of suspended solids could signify excessive erosion and a potential for filling of the lake basin. In contrast, if the suspended solids are primarily biodegradable organic materials produced within the lake itself, high suspended solids would not necessarily indicate either of the above conditions.

Sulfate

Major sources of sulfate are fertilizers, weathering of rocks, and atmospheric deposition primarily associated with entrained sea salts and combustion of fossil fuels. The latter is a major source of sulfate and acid rain, since sulfur compounds form one of the major components of acid rain. Thus, changes in sulfate concentrations over time could be an indicator of acid rain, although changes in alkalinity and pH yield more important information in this regard.

Sulfur is a component in some amino acids and, therefore is an essential element to all living organisms. It is generally found in abundance, so it rarely, if ever, limits production in natural aquatic systems. In the absence of oxygen, sulfate is reduced to H_2S, so eutrophic lakes are often vertically stratified with respect to these compounds: sulfate at the surface, hydrogen sulfide at the bottom.

After sodium and chloride, sulfate is one of the major ions of salt waters. High levels of sulfate, therefore, can occur naturally near the ocean or in estuarine systems.

Phytoplankton Taxa and Biomass

See page 1-29 through 1-34 of the coursebook for a review of biological lake components.

Phytoplankton taxa can provide information on lake status, since certain taxa (e.g., large blue-greens) tend to dominate eutrophic lakes. Phytoplankton cell counts are not a good indicator of algal biomass, however, because individual phytoplankton cells from different taxa can differ in mass by four or more orders of magnitude. Chlorophyll a, the major photosynthetic pigment of phytoplankton, offers a better indicator of algal biomass.

Lakes can be classified on the basis of chlorophyll a concentrations. For example, the OECD (1982) classifies mesotrophic lakes as those having average chlorophyll a concentrations ranging from 2.5 to 8 mg/m^3. Eutrophic lakes tend to have greater than 8 mg/m^3, and oligotrophic lakes tend to have less than 2.5 mg/m^3.

RELATIVE COST-EFFECTIVENESS OF WATER QUALITY PARAMETERS

Given limited resources and the need for regular sampling, the lake manager must decide which parameters yield the most information for the least money. Unfortunately, while certain parameters are usually cost-effective in any situation, the cost-effectiveness of others will vary from lake to lake. The following is a brief assessment, based on experience in New England, of the most cost-effective analyses.

1. Parameters that should be measured in almost every case.

Parameters which should be measured by DEM staff.

The following parameters—water temperature, dissolved oxygen, Secchi-disk depth, pH, total phosphorus, and macrophyte taxonomic distribution and density—should probably be measured in all cases since they are either very inexpensive or very important.

Water temperature has many important effects on water chemistry and biology both directly through impacts on bio- chemical processes and indirectly through thermal stratification. Temperature meters are inexpensive and long-lived; thus, after the initial capital investment, temperature readings are very inexpensive. Temperature readings taken during the period of potential stratification (May to October) are probably one of the most cost-effective of all diagnostic tools, especially in deeper lakes prone to stratification.

Given the impact of dissolved oxygen concentrations on fish health and phosphorus dynamics, dissolved oxygen is also a very important parameter. Data on temporal and spatial distribution of dissolved oxygen is especially important in stratified lakes and in lakes with dense vegetation having periodic fish kills. When investigating the latter, measurements should be taken right before sun rise when oxygen concentrations are at a minimum.

The cost for analysis of oxygen depends primarily on the technique. Precise chemical methods can be fairly expensive (up to $20 per sample), but less expensive and less accurate chemical methods can be found in simple water quality kits (e.g., Hach kits). Oxygen meters are somewhat expensive ($300 to $1000) but should last a relatively long-time (> 5 years) with very low upkeep costs. Once purchased, meters provide accurate readings quickly and repetitively. They are simple to operate and can provide a large number of readings quickly.

The pH of a water body should be measured in most cases because it is very important to the biology of the lake, subject to external forces in the form of acidic precipitation, and easy and inexpensive to measure. Electrode meters are relatively inexpensive and long-lived and provide numerous readings quickly and easily.

Secchi disk readings are also recommended because they are so inexpensive and easy and because they directly measure water clarity. Reductions in clarity occur with increases in algal biomass and with increases in sediments washed in from the watershed. Both of these phenomena will reduce the long-term health of the lake, and the Secchi disk offers a simple, reliable method to track changes in these parameters.

The concentration of total phosphorus should also be measured in almost all cases. As explained above, phosphorus is most often the critical element in plant growth, and thus, the most important single predictor of lake trophic status. Depending on the laboratory, phosphorus analyses can cost from $15 to $40 per sample.

However, several factors limit cost-effectiveness of analyzing phosphorus concentrations. Total phosphorus concentrations can vary significantly over a single year and from year to year (by factors of 2 or 3 or more); thus, many samples must be taken to get an accurate idea of the true phosphorus level in a system. In addition, rooted plants can derive almost all of their phosphorus from the sediment, so in-lake concentrations can be misleading in terms of nuisance plant growth. In the latter case, characterization of water column phosphorus may not be cost-effective in terms of weed management, although high water column phosphorus probably indicates a continuing source of pollution to the water body.

A survey of the density, distribution, and taxonomic composition of the macrophyton is almost always cost-effective when studying New England lakes. Most are small and relatively shallow with extensive littoral zones, conditions that foster excessive macrophyte growth. This is a common problem faced in lakes, and feasibility options depend on the species and densities of macrophytes present.

2. Parameters that should be measured in more in-depth investigations.

Additional parameters which may be necessary for DEM investigations.

The following parameters are recommended in most texts on the subject, but yield less information per sampling dollar than the parameters above. They are also somewhat difficult to interpret.

Concentrations of the various forms of nitrogen are generally measured in lake monitoring studies, since nitrogen is the second most important plant nutrient. Total Kjeldahl nitrogen, nitrate, and ammonia are most commonly recommended for measurement. Analysis for nitrite is also sometimes recommended, but this advice should be ignored in most cases, since nitrite is rarely present in appreciable quantities.

However, measurement of all four or three parameters can be relatively expensive, costing from $40 to $75 per sample. Moreover, the information gained is often not very useful. These expensive analyses are often justified so that the limiting nutrient--nitrogen or phosphorus--can be identified by the ratio of total nitrogen to total phosphorus. However, in many eutrophic lakes with high phosphorus and low N:P ratios, both nitrogen and phosphorus concentrations occur in abundance, and neither nitrogen nor phosphorus limits plant growth. Even in those cases where nitrogen availability does limit plant growth, lake managers generally try to reduce phosphorus inputs instead, because phosphorus is much easier to control.

Soluble phosphorus is another parameter that can be very useful in certain situations. Low soluble phosphorus levels can be used as evidence of phosphorus limitation, and high levels usually indicate the opposite. However, as with the case with N:P ratios, most lake management focuses on phosphorus control even when other nutrients are limiting, so the value of this parameter is limited.

For various reasons, nevertheless, the nitrogen species should be measured in cases where funds are available. Measurement of total nitrogen is important to isolate or detect pollution loading, and ammonia may reach toxic levels in hyper-eutrophic systems after plant die-offs. Moreover, measurement of nitrogen levels provide another base-line to detect changes over time.

Alkalinity should be measured in those lakes with low pH or in areas where nearby lakes are undergoing acidification. Chloride and conductivity should be measured periodically in systems to determine whether road salts are impacting aquatic resources. All three analyses are fairly inexpensive--$10 to $20 per test per sample.

For swimming beaches, bacteria monitoring is essential. For other lakes, bacteria can be a somewhat useful monitoring tool for septic contamination, although non-human fecal contamination can often hide or mimic the presence of human wastes. To differentiate between human and non-human sources, both fecal coliform and fecal streptococci should be measured in the same waters. Adequate bacterial sampling can be very expensive. Per sample, bacteria analyses are only moderately expensive, about $15 to $25 per analysis. However, samples must be taken often and at many places, because bacteria populations can vary dramatically over very short times and distances.

Chlorophyll a and phytoplankton taxonomic identification are useful indicators of trophic state. However, phytoplankton populations tend to vary dramatically over time depending on a number of factors; thus, small numbers of samples yield useful, but limited data. These analyses tend to be moderately expensive--$20 to $30 for each sample--and are sometimes difficult to interpret. Like nitrogen compounds, they are essential for an in-depth analysis by an expert in limnology, but are of somewhat less value to the lake manager in the field.

Suspended solids are a useful, inexpensive indicator of algal biomass in many lakes. When measured in conjunction with indicators of algal biomass, this parameter can be used to indicate periods of high non-algal turbidity.

Sulfate levels can be used to monitor for heavy inputs of acid rain. However, changes in pH and alkalinity are more direct indicators of impacts, so this parameter should be measured to confirm cases where alkalinity and/or pH have fallen over time.

DIAGNOSTIC STUDY METHODOLOGY

a. Useful Information

See page 3-21 through 3-22 of coursebook.

1. Lake Management Objectives
    - Existing and desired uses of the lake
    - Priority of uses
    - Special features which must be considered

2. Physical Lake Features
    - Map of lake shape, lake area
    - Map of water depth, mean and maximum depths, volume
    - Map of soft sediment depth

3. Physical Watershed Features
    - Detailed topographic maps
    - Watershed delineation
    - Sub-watershed delineations
    - Map of land uses
    - Delineation of sewered and non-sewered areas
    - Delineation of storm drainage pipelines
    - Geology and soils maps

4. Historical Information on Lake and Watershed Uses
    - Old accounts
    - Old maps

5. Limnological Data
    - Flow (surface and ground waters)
    - Water quality (nutrients, pH, oxygen, bacteria, etc.)
    - Sediment quality (organic content, nutrients, metals)
    - Biological quality (algae, vascular plants, invertebrates, fish)

b. Key Indicators: Watershed

See page 3-23 of coursebook.

1. Watershed: lake area ratio
2. Erodibility of soils
3. Land use
4. Road density
5. Lake access

c. Key Indicators: Lake

1. Lake area
2. Shallowness ratio
3. Hydraulic residence time
4. Shoreline development
5. Water clarity
6. Littoral zone plant coverage
7. Bottom sediment type
8. Presence of specific biota

d. Water Quality Monitoring

See page 3-23 through 3-32 of coursebook.

1. Design considerations
   - parameters to be assessed
   - stations to be sampled
   - frequency of sampling
   - cost
   - laboratory turnaround time
   - statistical needs
   - sampling protocol

2. Typical parameters
   - water flow (velocity X area)
   - total phosphorus
   - soluble reactive phosphorus
   - total soluble phosphorus
   - ammonium nitrogen
   - nitrate nitrogen
   - total Kjeldahl nitrogen
   - dissolved oxygen
   - temperature
   - alkalinity
   - pH

- conductivity
- total dissolved solids
- chlorides
- total suspended solids
- turbidity
- Secchi disk transparency
- chlorophyll a
- iron
- fecal bacteria

3. Sampling stations
    - vertical levels in distinct lake basins
    - inlet streams/pipes
    - outlet(s)
    - key upstream points

4. Sampling frequency
    - daily
    - weekly
    - monthly
    - seasonally
    - annually

5. Costs
    - sample collection
    - sample analysis
    - data analysis

6. Laboratory turnaround time
    - holding time
    - analysis time
    - data processing time

7. Statistical needs
    - precision
    - accuracy
    - significant differences

8. Sampling protocol
    - sample containers
    - sample volumes
    - preservation
    - labelling
    - representative sampling
    - compositing
    - flow measures
    - field notes

e. Pollutant Loadings and Budgets

See page 3-32 through 3-33 of coursebook.

1. Purpose

2. Evaluating loads
    - export models
    - in-lake models
    - empirical data

3. Constructing budgets

DETERMINING APPROPRIATE LAKE USES

a. Range of Uses

See page 3-33 through 3-35 of coursebook.

1. Contact recreation
2. Passive uses/aesthetics
3. Non-power boating
4. Power boating/skiing
5. Fishing
6. Hunting
7. Consumptive supply
8. Power supply
9. Cooling supply
10. Flood control
11. Ice sports

See page 3-36 through 3-41 of coursebook.

b. Influence of Watershed Features on Lake Uses

c. Influence of Lake Features on Lake Uses

d. Influence of Lake Use on Lake Features

e. Influence of Lake Uses on Other Lake Uses

f. Establishing Priorities

1. Lake/watershed analysis
2. User surveys
3. Building concensus

TABLE 3.1

INFORMATION USEFUL TO THE MANAGEMENT OF LAKES AND PONDS

The following list includes pieces of information which are useful and in many cases necessary to the effective management of an aquatic system. The level of detail required varies among systems, and some items might even be inapplicable to certain systems.

A. Lake Management Objectives
   1. Existing and desired uses of the lake
   2. Priority of uses
   3. Special features which must be considered

B. Physical Lake Features
   1. Map of lake shape, lake area
   2. Map of water depth, mean and maximum depths, volume
   3. Map of soft sediment depth

C. Physical Watershed Features
   1. Detailed topographic maps of area
   2. Watershed delineation
   3. Sub-watershed delineations
   4. Map of land uses
   5. Delineation of sewered and non-sewered areas
   6. Delineation of storm drainage pipelines
   7. Geology and soils maps

D. Historical Information on Lake and Watershed Uses
   1. Old accounts
   2. Old maps

E. Limnological Data
   1. Flow (surface and ground waters)
   2. Water quality (nutrients, pH, oxygen, bacteria, etc.)
   3. Sediment quality (organic content, nutrients, metals)
   4. Biological quality (algae, large plants, invertebrates, fish)

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.2

COMMONLY ASSESSED MONITORING PARAMETERS WITH NOTES ON ASSOCIATED COST AND UTILITY

PARAMETER	UNIT OF ANALYSIS	RANGE OF COST FOR ANALYSIS ($)	NOTES ON PARAMETER UTILITY
Flow	station	5-50	Essential for pollutant budgets and hydrology
Total phosphorus	sample	10-40	Critical plant nutrient, all forms
Soluble reactive phosphorus	sample	8-20	Critical plant nutrient, readily available form
Total soluble phosphorus	sample	10-40	Critical plant nutrient, assumed bioavailable form
Ammonium nitrogen	sample	10-25	Critical plant nutrient, possible health risk
Nitrate/nitrite nitrogen	sample	8-20	Critical plant nutrient, possible health risk
Total Kjeldahl nitrogen	sample	20-50	Ammonium plus organic nitrogen forms
Dissolved oxygen	station	5-25	Essential for most desirable forms of aquatic life
Temperature	station	2-5	Affects many reactions, solubilities, process rates
Alkalinity	sample	5-15	Indicates buffering capacity for acid inputs
pH	sample	5-15	Indicates level of acid concentration
Conductivity	sample	5-15	Indicates dissolved substances and overall fertility
Total dissolved solids	sample	10-25	Fertility indicator, substances dissolved in lake
Chlorides	sample	5-15	Salt indicator, often major dissolved substance
Sodium	sample	5-15	Potential health risk, common dissolved substance
Total suspended solids	sample	12-25	Represents all particle forms in water
Turbidity	sample	5-15	Clarity indicator, related to suspended solids
Secchi disk transparency	station	2-5	Clarity indicator, related to suspended solids
Iron	sample	8-20	Important and common metal, taste factor, P binder
Other trace metals	sample	12-25	Variety of possibly toxic metals, health risks
Chlorine	sample	8-15	Result of chlorination, treatment facility marker
Sulfate	sample	8-15	Substrate for anaerobic metabolism, acid indicator
Color	sample	8-15	Related to dissolved substances and visual properties
Odor	sample	8-15	Related to dissolved substances and sensory features
Biochemical oxygen demand	sample	25-50	Level of oxygen removal through decomposition
MBAS surfactants	sample	25-50	Detergent indicator, aid in sorting P sources
Oil and grease	sample	25-80	Suggests organic matter level, possible toxicity
Total organic carbon	sample	30-60	Suggests organic matter level, possible toxicity
Volatile organic compounds	sample	110-200	Scan of variety of possibly toxic materials
Pesticide scan	sample	75-150	Scan of variety of possibly toxic materials
PCB's	sample	60-125	Possible health risk, human impact indicator
Fecal coliform	sample	8-30	Possible health risk, sewage contamination indicator
Fecal streptococci	sample	8-30	Modifies assessment via fecal coliform
Chlorophyll a	sample	25-60	Represents algal biomass, clarity indicator
Phytoplankton abundance	sample	30-100	Eval. of community structure, ecological indications
Zooplankton abundance	sample	30-100	Indicates grazing potential, food for small fish
Macrophyte abundance	lake	1000-5000	Suggests nuisance potential, ecological indications
Macroinvertebrate abundance	sample	30-100	Suggests sediment quality, fish food resource
Fish community structure	lake	1000-5000	Eval. of community structure, ecological indications

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.3

WATERSHED FEATURES WHICH INFLUENCE RECREATIONAL UTILITY AND IMPACTS

1. **Watershed:lake area ratio**
   a. Low (<10:1)
   b. Medium (10-25:1)
   c. High (25-50:1)
   d. Very high (>50:1)

2. **Erodibility of soils**
   a. Low (high permeability, flat slopes, high cover)
   b. Medium (one of above opposite, others same)
   c. High (two of above opposite, other same)
   d. Very high (low permeability, steep slopes, low cover)

3. **Land use**
   a. Dominated by forest or wetland
   b. Dominated by agriculture (excluding sugarbush)
   c. Dominated by urbanized uses

4. **Road density**
   a. Low
   b. Medium
   c. High
   d. Very high

5. **Lake access**
   a. No formal access
   b. Primitive trails or beaches
   c. Developed boat ramps or beaches

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.4

LAKE FEATURES WHICH INFLUENCE RECREATIONAL UTILITY AND IMPACTS

1. Lake area
   a. Low (<20 ac)
   b. Medium (20-100 ac)
   c. Large (100-300 ac)
   d. Very large (>300 ac)

2. Shallowness ratio
   (area <5 ft deep/total area)
   a. Low (<0.10)
   b. Medium (0.10-0.25)
   c. High (0.25-0.50)
   d. Very high (>0.50)

3. Hydraulic residence time
   a. (<21 days)
   b. (21-90 days)
   c. (90-365 days)
   d. (>365 days)

4. Shoreline development
   (shoreline length/circumference of circle with lake area)
   a. Low (<1.5)
   b. Medium (1.5-3.0)
   c. High (>3.0)

5. Water clarity
   a. Low (<4 ft)
   b. Medium (4-8 ft)
   c. High (8-15 ft)
   d. Very high (>15 ft)

6. Littoral zone coverage by plants
   a. Low (<25%)
   b. Medium (25-50%)
   c. High (50-75%)
   d. Very high (75-100%)

7. Bottom sediment type
   a. Cobble
   b. Gravel or sand
   c. Silt or clay
   d. Organic muck
   e. Boulders or stumps

8. Presence of specific biota
   a. Parasites or other nuisance species
   b. Rare or endangered populations
   c. Fish desired by anglers
   d. Waterfowl desired by hunters

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

LAKE SAMPLING EQUIPMENT

Determination of Physical Factors

See page 1-8 through 1-21 of coursebook for a review of physical factors.

The measurement of depth for bathymetric contours can be simply determined with a **sounding line** (a calibrated line with a weight) or a measuring rod. The recent development of relatively inexpensive depth sounders or **fathometers** provides a more convenient and rapid way of establishing depth. The higher cost of the latter may be somewhat compensated by the decreased manpower requirements. These devices are hampered somewhat by the presence of heavy macrophyte growth.

Measurement of temperature within the water column can be accomplished through a variety of instruments, some elaborate and designed for oceanographic work. These include conventional **mercury thermometers, reversing thermometers, bathythermographs,** and **thermistor electrical resistance thermometers.** The last is the most common piece of equipment used for field determinations.

Light condition measurements can range from simple to complex. The most simple of these is the **Secchi disk** determination, previously discussed in Section 1. A further refinement is provided by a **submersible photometer**, which incorporates a photocell to measure light intensity over a wide spectra of wavelengths. The most accurate quantification of light is with an **underwater spectroradiometer**, which provides direct measurement of light in discrete portions of the wavelength.

Determination of Chemical Factors

See page 1-21 through 1-29 of coursebook for a review of chemical factors.

Collection of water samples for water chemistry is an integral part of field limnology. One of the most important collection areas is that of bottom water, so it is very important to accurately sample water at a given depth. A diverse collection of sampling gear has been developed to perform this function, mostly identified by the name of their inventor. These include the

Kemmerer, Van Dorn and **Scott** water sampling bottles. The principle operation of these bottles is similar--the bottle is lowered in an open position to the desired depth and then is closed through the use of a weight (called the "**messenger**") or other manipulations of the line. A recent trend in water bottle manufacture has been to replace metal with PVC, or other inert materials, to prevent possible contamination of the sample with dissolved metals.

One of the most instructive parameters to diagnose lake or pond conditions is the levels of dissolved oxygen. Determination of oxygen levels is usually done by chemical titration of collected water samples through the **Winkler method**, or direct measurement taken through the use of an **oxygen electrode probe**. The Winkler method is well-established and is very accurate, if precautions regarding the handling of the water sample are made and special glassware is used. The oxygen probe requires fairly frequent calibration but provides a much quicker assessment of the oxygen profile (changes with depth). A useful combination of a thermistor and oxygen probe is commonly used as it allows for simultaneous determination of the two during the same lowering. This proves very useful in conserving sampling effort and time.

In addition to the absolute amounts of oxygen, it is also useful to know the amount of oxygen relative to the maximum possible total. This is the **100 percent saturation** total. The 100% saturation total changes with temperature to compensate for the changes in the solubility of oxygen. The maximum amount of dissolved oxygen in water is inversely related to temperature. The lower the temperature the higher the dissolved oxygen content at equilibration with the atmosphere. This is one reason why sensitive fish, such as trout, inhabit cooler waters in summer to seek higher oxygen levels. Determination of percent saturation is done by consulting standard limnological tables which give the saturated total for a wide variety of temperatures. There are slight additional corrections for salinity or altitude variations.

Determination of Biological Factors

See page 1-29 through 1-34 of coursebook for a review of biological factors.

Measurement of the biological components of a lake or pond ecosystem involves sampling of the various trophic levels of the **food web**. The simplest way of collecting phytoplankton is analogous to the collection of water quality samples. Phytoplankton are often collected in the field and preserved with **Lugol's solution** for later inspection and identification with the microscope. Their relative scarcity in oligotrophic waters may be compensated by concentrating them through various means. A **phytoplankton net** can be towed through the water sieving out the particles of a size greater than about 100 microns (the so-called "**net plankton**"). In addition, large volumes of water can be filtered through a **membrane filter** of known pore size and the filter retained for microscopic inspection. Finally, preserved phytoplankton may be concentrated by settling out the algae by gravity under still conditions and inspection with an **inverted microscope**.

Determination and identification of macrophyte abundance is most commonly achieved with a combination of observation from the boat, and use of a **grappling hook** for collecting specimens from deeper waters. Alternatively, direct observation of bottom conditions may be extended over large portions of the lake bottom through snorkeling, or the use of SCUBA divers. Measurement of the abundance of individual species of macrophytes are notoriously qualitative in nature, and often referred to as "dominant", "common" or "rare" categories. Quantification of biomass may be achieved through collection and weighting of materials from a known area (e.g., a weighted hula-hoop).

The collection, identification and enumeration of the zooplankton is similar in nature to the phytoplankton net collection. Sampling is done through repeated "**casts**" of the zooplankton net and tows through the water. Zooplankton are typically preserved in a formaldehyde-sugar solution for later analysis. Identification is commonly done through microscopic inspection, or the projection of silhouetted shapes on a viewer.

Sampling of the benthic community requires collection of an appreciable portion of the physical habitat of these animals, namely the bottom muds. Collection of these sediments is achieved through a variety of samplers. The most commonly employed sampler is the **Ekman benthic dredge**, a steel box with jaws that open when lowered and close upon firing to encapsulate a portion of the bottom sediment. Variations on this theme include the **Ponar** and **Petersen** dredges. Once the material has been collected it is passed through a sieve to collect the benthic animals (also known as the benthos). Insects which inhabit or are associated with the aquatic macrophytes can be collected through standardized sweeps of the plant area with a D-frame dip net. The collected insects are typically preserved in an ethanol solution for later identification with a dissecting microscope or hand lens.

Determinations of fish communities can be achieved with a combination of visual observations, habitat assessments and creel (angler) surveys. More quantifiable fish collections can be made with a variety of nets including **gill nets, shoreline seine nets,** and **trap or fyke nets.** Electroshocking of shoreline areas are useful in turning up smaller species which may not be caught by conventional nets. Surveying by poisoning a portion of the water with rotenone and identifying casualties was once a common practice by fishery personnel but now represents an outmoded methodology not acceptable to today's environmental practices.

A list of sampling methodologies, materials and equipment typically used for lake assessment and monitoring follows:

SAMPLE COLLECTION AND PROCESSING METHODOLOGY

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Percent oxygen saturation	Calculation from T/DO			H&L CH.6			
pH	Potentiometric	423	150.1	H&L CH.8			2
Total alkalinity	Titration	403	310.1	H&L CH.8	200	Refrigerate	24
Chloride	Titration	407 A,B,C	325.3	H&L CH.7	100	Refrigerate	672
Specific conductance	Platinized electrode	205	120.1	H&L CH.7		Refrigerate	672
Secchi disk transparency	Visual			H&L CH.2 P			Immediate
Turbidity	Nephelometric	214 A	180.1		50	Darkness	24
Total solids	Gravimetric (dried)	209 A	160.3	H&L CH.7	500	Refrigerate	168
Total volatile solids	Gravimetric (ignited)	209 E	160.4	H&L CH.7	500	Refrigerate	168
Total suspended solids	Gravimetric (filtered/dried)	209 B	160.1	H&L CH.7	500	Refrigerate	168
Arsenic	Atomic absorption	303 E	206.1&2		50	HNO3 to pH<2	6 months
Cadmium	Atomic absorption	303 A	213.1&2		50	HNO3 to pH<2	6 months
Chromium	Atomic absorption	303 A	218.1&2		50	HNO3 to pH<2	6 months
Copper	Atomic absorption	303 A	220.1&2		50	HNO3 to pH<2	6 months

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

SAMPLE COLLECTION AND PROCESSING METHODOLOGY

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Iron	Atomic absorption Colorimetric	303 A 315 B	236.1&2		50	HNO3 to pH<2	6 months
Lead	Atomic absorption	303 A	239.1&2		50	HNO3 to pH<2	6 months
Manganese	Atomic absorption	303 A	243.1&2		50	HNO3 to pH<2	6 months
Mercury	Atomic absorption	303 F	245.1&2 245.5		500	HNO3 to pH<2	6 months
Nickel	Atomic absorption	303 A	249.1&2		50	HNO3 to pH<2	6 months
Vanadium	Atomic absorption	303 C	286.1&2		50	HNO3 to pH<2	6 months
Zinc	Atomic absorption	303 A	289.1&2		50	HNO3 to pH<2	6 months
Oil and grease	Extraction/gravimetric	503 A,C	413.1		1000	H2SO4 to pH<2	672
Polychlorinated biphenyls	Gas chromatographic			FR			
Pesticides (general scan)	Gas chromatographic			FR			
Organic content	Gravimetric (dried/ignited)	209 E	160.4				
Grain size distribution	Gravimetric (sieved)			H&L CH.5 H&B			
Sediment settling features	Volumetric			H&B			
Fecal coliform	Incubated filter plate count	909 C		B&H III.C.2	125	Refrigerate	6
Fecal streptococci	Incubated filter plate count	910 B		B&H III.D.2	125	Refrigerate	6

SAMPLE COLLECTION AND PROCESSING METHODOLOGY

PARAMETER	COLLECTION/TEST TYPE	STD. METH	EPA METHOD	OTHER METHOD	RECOMMENDED SAMPLE SIZE (ml)	SAMPLE PRESERV.	RECOMMENDED HOLDING TIME (hr or as noted)
Chlorophyll a	Extraction/absorption	1003 B.3	W CH.2.5.2.1&3	W&L CH.10	1000	Refrigerate in dark	8
Biological collections							
Phytoplankton	Grab or tube composite	1002 B.2&3	W CH.2.2&3	W&L CH.10		Lugol's	6 months
Zooplankton	150 um mesh net tow	1002 B.2&4	W CH.2.2&3	W&L CH.11		Formalin	6 months
Macrophytes	Ekman or manual	1004 D.1 1004 D.2a&b	W CH.3	W&L CH.20		Formalin	48
Macroinvertebrates	D-net or Ekman dredge	1005 B.3.a.6 1005 B.4	W CH.4.3.2&3 W CH.4.4.1&2	W&L CH.12		Alcohol or formalin	6 months
Fish	Gill net, trap net or seine	1006 A.1.abd	W CH.5.2.2.1 W CH.5.2.3	NJL CH.6,7,18&19		Alcohol or formalin	6 months
Phytoplankton abundance	Microscopic cell count	1002 C.1 1002 E.1&4 1002 F.1&2 1002 H.2	W CH.2.4&5.3	W&L CH.10			
Zooplankton abundance/ size distribution	Microscopic count	1002 C.1 1002 E.1&4 1002 F.7 1002 H.2	W CH.2.4&5.3	W&L CH.11			
Macrophyte abundance/ distribution	Visual	1004 B 1004 C.1,2&4 1004 D.3&4	W CH.3	W&L CH.20			
Macroinvertebrate abundance	Visual or microscopic examination	1005 C	W CH.4.4.5	W&L CH.12			
Fish abundance/growth rate	Visual and microscopic scale examination	1006 B	W CH.5.4	NJL CH.15&16			
Soft sediment depth	Probe to refusal			DEQE			
Lake bathymetry	Sonic fathometer			W&L CH.1 DEQE			
Morphometric lake features	Physical/calculation			W&L CH.1			

REFERENCES FOR METHODOLOGY:

Unless otherwise given, Std. Method is from APHA-AWWA-WPCF 16th edition.
Unless otherwise given, EPA Method is from EPA-600/4-79-020.

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FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
FIELD WORK: Water Sample Collection - General field needs		Vehicle, first aid kit, flashlight, tools/repair supplies Boat, trailer, oars, motor, fuel tank/line, rope, life jackets, seat cushions, fire extinguisher, light/whistle safety assembly and anchors Ice auger, toboggan/sled, ice ladle Boots/waders, rubber gloves, rain gear Coolers, carrying crates, labels/tape, marking pens, pencils, paper/clipboards, field notebooks, waterproof notebook, lab/field sheets, maps Assorted sample containers, preservatives (specific needs below)
Surface water	Grab	1 to 4 L jug or jar, Scott bottle, funnel, extension poles/tape
Stormwater runoff	Grab or composite	1 to 4 L jug and jar
Groundwater Wells	Grab	1 to 4 L jug or jar, well logger, well bailer or pump
Porewater	Grab or composite	1 to 4 L jug or jar, LIP sampler w/hand pump and trap
Seepage	Volumetric	Seepage meters w/bags and spouts, grad. cyl., tape measure, float-markers, watch
Biological Collections - Bacteria	Grab	Sterile plastic bags or glass bottles
Phytoplankton	Grab or tube composite	100 to 250 ml bottles w/Lugol's solution, 10 m flexible tube (1 to 2 cm dia.), 1 L dark bottle (for chl)
Zooplankton	150 um mesh net tow	250 to 500 ml bottles w/formalin, 150 um mesh tow net, calibrated rope
Macrophytes	Ekman or manual	Ekman dredge, areal grid sampler, plastic bags, SCUBA gear, ident. manuals
Macroinvertebrates	D-net or Ekman dredge	Ekman dredge, D-net, sorting pan, forceps, 500 ml jars, alcohol or formalin, std. seives
Fish	Gill net, trap net or seine	Gill net, trap net, seine, net pickers, live well, measuring board, weighing scale, needle nose pliers, scale envelopes, dip net

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Sediment Sampling and Physical Measurements -		
Sediment collection	Core or Ekman grab	Ekman dredge, lucite core tubes, mixing bucket, glass and plastic widemouth containers, SCUBA gear
Soft sediment depth	Probe to refusal	Graduated rods with screw connections, SCUBA gear
Water discharge (flow)	Volumetric	Floats, Gurley meter, stopwatch, tape measure/graduated rod
Lake bathymetry	Sonic fathometer or line soundings	Electronic fathometer assembly, graduated plumbline, operated from a boat
Morphometric lake features	Physical/calculation	Maps, ruler, planimeter, measuring wheel, calculator/computer (typically done in office after field reconnaisance)
Field Analyses -		
Secchi disk transparency	Visual	20 cm Secchi disk on graduated rope
Temperature	Thermistor	Thermistor (incl. w/DO and Cond. meters) on 30 m cable
Dissolved oxygen	Membrane electrode or Winkler titration	VSI Model 57 or modified Model 51A or equivalent DO meter w/30 m cable, probe repair kit Winkler chemicals, pipettes, titration apparatus, stoppered bottle for sample
Percent oxygen saturation	Calculation from T/DO	Calculator/computer; can be done in field or in office/lab later
pH	Potentiometric	Orion SA250 pH meter or equivalent, pH 4, 7 &10 buffers, distilled water. Hach colorimetric kits can be used for field approximation; pH meter can also be used in lab.
Specific conductance	Platinized electrode	VSI Model 33 S-C-T meter or equivalent, conductivity standard, platinizing solution, distilled water; can also be used in lab
Turbidity	Nephelometric	Hach Model 1860 turbidimeter or equivalent, power source, paper towels, distilled water; can also be used in lab

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
LABORATORY ANALYSES: General laboratory needs		Refrigerator/freezer, cabinets/benchtops, hood/overall ventillation system, electronic balance, drying oven, muffle furnace, autoclave, dessicator, incubator, titration apparatus, distillation apparatus, magnetic stirrer assembly, 2 nm band width spectrophotometer, acid wash assembly, rubber gloves, cleaning supplies (incl. acids and non-P detergent), goggles, chemical handling supplies (scoops, paper, etc.), alarm timer, distilled water source, shower/eye wash, assorted glassware Some items are repeated below where used
Total phosphorus	Colorimetric	424C-Persulfate digestion- hot plate or autoclave, autoclavable, acid-washed glassware, phenophthalein indicator, sulfuric acid, ammonium persulfate, sodium hydroxide 424F-Ascorbic acid method- See SRP below
Total filterable phosphorus	Colorimetric	424A-Filtration step- 0.45 um membrane filters, suction filtration apparatus, acid washed collection vessel 424C- Persulfate digestion- See TP above 424F-Ascorbic acid method- See SRP below
Soluble reactive phosphorus	Colorimetric	424F-Ascorbic acid method- Acid-washed glassware, spectrophotometer w/5-10 cm path, sulfuric acid, potassium antimonyl tartrate solution, ammonium molybdate solution, ascorbic acid solution, stock P solution
Nitrate nitrogen	Colorimetric	418B-Electrode method- pH meter, nitrate electrode, magnetic stir apparatus, stock nitrate solution 418C-Cadmium reduction method- Reduction column, spectrophotometer w/1 to 5 cm path, copper-cadmium granules, sulfanilamide reagent, N(1-naphthyl)-ethylenediamine dihydrochlorids solution, ammonium chloride-EDTA solution, hdrochloric acid, copper sulfate solution, stock nitrate solution, membrane filters, suction filter apparatus 418D-Chromotropic acid method- Spectrophotometer w/1 to 5 cm path, stock nitrate solution, sulfite urea solution, antimony reagent, chromotopic acid reagent, sulfuric acid

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Ammonia nitrogen	Colorimetric	417A-Distillation step- Ammonia-free water, distillation apparatus, borate buffer solution, sodium hydroxide, dechlorinating agent, phenylarsine oxide, sodium arsenite, sodium sulfite, sodium thiosulfate, neutralization agent, sodium hydroxide, sulfuric acid, boric acid 417B-Nesslerization- Spectrophotometer w/1 to 5 cm path, Nessler tubes, pH meter, zinc sulfate solution, EDTA, Nessler reagent, stock ammonium solution, potassium chloroplatinate solution, cobaltous chloride solution, membrane filters, suction filter apparatus 417D-Electrode method- pH meter, ammonia electrode, magnetic stirrer apparatus, ammonia-free water, sodium hydroxide, stock ammonia solution
Total kjeldahl nitrogen	Colorimetric	420B-Semi-micro-Kjeldahl method- Digestion apparatus, distillation apparatus, pH meter, digestion reagent (potassium sulfate, mercuric oxide, sulfuric acid), phenolphthalein indicator, sodium hydroxide-sodium thiosulfate reagent, borate buffer and sodium hydroxide 417B or 417E- See ammonia above
Total alkalinity	Titration	403-Std. Method- sodium carbonate solution, sulfuric or hydrochloric acid, mixed bromocresol green-methyl red indicator, methyl orange solution, phenophthalein indicator, sodium thiosulfate
Chloride	Titration	407A-Argentometric method- Potassium chromate indicator, silver nitrate solution, standard sodium chloride, titration apparatus
Total solids	Gravimetric (dried)	209A-Std. Method- Evaporating dish, muffle furnace, steam bath, drying oven, dessicator, balance
Total volatile solids	Gravimetric (ignited)	209E-Std. Method- No additions to 209A 209A- See Total Solids above
Total suspended solids	Gravimetric (filtered/dried)	209D-Std. Method- glass fiber filters, suction filter apparatus, crucibles or planchets, in addition to 209A 209A- See Total Solids above
Arsenic	Atomic absorption	Atomic absorption unit and related supplies, argon-hydrogen or nitrogen-hydrogen gas
Cadmium	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Chromium	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Copper	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Iron	Atomic absorption Colorimetric	Atomic absorption unit and related supplies, air-acetylene gas 315B-Phenanthroline method- Spectrophotometer w/1 to 5 cm path, Nessler tubes, acid-washed glassware, separatory funnels, membrane filters, suction filtration apparatus, hydrochloric acid, hydroxylamine solution, ammonium acetate buffer solution, sodium acetate solution, phenanthroline solution, stock iron solution
Lead	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Manganese	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Mercury	Atomic absorption	Atomic absorption unit and related supplies, cold vapor method supplies
Nickel	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Vanadium	Atomic absorption	Atomic absorption unit and related supplies, nitrous oxide-acetylene gas
Zinc	Atomic absorption	Atomic absorption unit and related supplies, air-acetylene gas
Oil and grease	Extraction/gravimetric	503A-Partition/gravimetric method- Separatory funnel, distillation apparatus, water bath, filter paper, gravity filtration apparatus, hydrochloric acid, trichlorotrifluoroethane, sodium sulfate
Polychlorinated biphenyls	Gas chromatographic	Gas chromatograph and related supplies
Pesticides (general scan)	Gas chromatographic	Gas chromatograph and related supplies
Organic content	Gravimetric (dried/ignited)	209E- See Total Volatile Solids above

FIELD/LABORATORY ANALYSES AND EQUIPMENT

PARAMETER	COLLECTION/TEST TYPE	EQUIPMENT NEEDS
Fecal coliform	Incubated filter plate count	909C-Membrane filter procedure- M-FC medium, culture dishes, incubator, pipettes, sterile filter apparatus, membrane filters, absorbent pads, forceps, fluorescent lamp with magnifying lens (10 to 15X), suction filter apparatus
Fecal streptococci	Incubated filter plate count	910B-Membrane filter procedure- KF Streptococcus agar, culture dish incubator, pipettes, sterile filter apparatus, membrane filters, absorbent pads, forceps, fluorescent lamp with magnifying lens (10 to 15X), suction filter apparatus
Grain size distribution	Gravimetric (sieved)	ASTM seive series, hydrometer, collection pans, balance
Sediment settling features	Volumetric	Large and small settling columns (clear tubes, pref. graduated, with sampling/outlet ports at intervals), watch
Chlorophyll a	Extraction/absorption	0.45 um filter paper, Millipore suction filter apparatus or equivalent, 90% acetone solution, tissue grinder, graduated test tubes, spectrophotometer w/2 nm band width, conc. H2SO4
Phytoplankton abundance	Microscopic cell count	Graduated settling tubes, Sedgewick-Rafter and Palmer-Maloney counting slides, microscope with capability of 100 to 400X, tally sheets, computer (w/tabulation/biomass conversion prog.), identification manuals, ocular measuring device
Zooplankton abundance/ size distribution	Microscopic count	Graduated settling tubes, Sedgewick-Rafter counting slide, microscope with capability of 40 to 100X (overhead proj. scope), tally sheets, computer (w/tabulation/biomass conversion prog.), identification manuals, ocular measuring device
Macrophyte abundance/ distribution	Visual	Hand lens, ident. manuals
Macroinvertebrate abundance	Visual or microscopic examination	Petri dishes, stereoscope with capability of 4 to 40X, dissection kit, ident. manuals, hand lens
Fish abundance/growth rate	Visual and microscopic scale examination	Ident. manuals, microscope with capability of 40 to 100X (overhead projector scope), flat microscope slides or acetate scale impressions, forceps, ocular measuring device

TABLE 105:I SUMMARY OF SPECIAL SAMPLING OR HANDLING REQUIREMENTS*

Determination	Container	Minimum Sample Size mL	Preservation	Maximum Storage Recommended/Regulatory†
Acidity	P.G(B)	100	Refrigeration	24 hr/14 days
Alkalinity	P.G	200	Refrigerate	24 hr/14 days
BOD	P.G	1.000	Refrigerate	6 hr/48 hr
Boron	P	100	None required	28 days/28 days
Bromide	P.G	—	None required	28 days/28 days
Carbon, organic, total	G	100	Analyze immediately: or refrigerate and add H_2SO_4 to pH < 2	7 days/28 days
Carbon dioxide	P.G	100	Analyze immediately	—/—
COD	P.G	100	Analyze as soon as possible: or add H_2SO_4 to pH < 2	7 days/28 days
Chlorine, residual	P.G	500	Analyze immediately	0.5 hr/2 hr
Chloride dioxide	P.G	500	Analyze immediately	0.5 hr/2 hr
Chlorophyll	P.G	500	30 days in dark: freeze	30 days/—
Color	P.G	500	Refrigerate	48 hr/48 hr
Conductivity	P.G	500	Refrigerate	28 days/28 days
Cyanide:				
Total	P.G	500	Add NaOH to pH > 12, refrigerate in dark	24 hr/14 days
Amenable to chlorination	P.G	500	Add 100 mg $Na_2S_2O_3$/L	—/—
Fluoride	P	300	None required	28 days/28 days
Grease and oil	G, wide-mouth, calibrated	1.000	Add H_2SO_4 to pH < 2: refrigerate	28 days/28 days
Hardness	P.G	100	Add HNO_3 to pH < 2	6 months/6 months
Iodine	P.G	500	Analyze immediately	0.5 hr/—
Metals, general	P(A), G(A)	—	For dissolved metals filter immediately, add HNO_3 to pH < 2	6 months/6 months
Chromium VI	P(A), G(A)	300	Refrigerate	24 hr/48 hr
Copper by colorimetry*				
Mercury	P(A), G(A)	500	Add HNO_3 to pH < 2, 4 C	28 days*/28 days
Nitrogen:				
Ammonia	P.G	500	Analyze as soon as possible or add H_2SO_4 to pH < 2, refrigerate	7 days/28 days
Nitrate	P.G	100	Add H_2SO_4 to pH < 2, refrigerate	48 hr/48 hr
Nitrate + nitrite	P.G	200	Analyze as soon as possible or refrigerate: or freeze at −20 C	none/28 days
Nitrite	P.G	100	Analyze as soon as possible or refrigerate: or freeze at −20 C	none/48 hr
Organic, Kjeldahl	P.G	500	Refrigerate: add H_2SO_4 to pH 2	7 days/28 days
Odor	G	500	Analyze as soon as possible: refrigerate	6 hr/—
Organic compounds:				
Pesticides	G(S), TFE-lined cap	—	Refrigerate: add 100 mg $Na_2S_2O_3$/L if residual chlorine present	7 days/7 days
Phenols	P.G	500	Refrigerate: add H_2SO_4 to pH < 2	*/28 days
Purgeables by Purge and Trap	G, TFE-lined cap	50	Refrigerate: add 100 mg $Na_2S_2O_3$/L if residual chlorine present	7 days/14 days
Oxygen, dissolved:	G, BOD bottle	300		
Electrode			Analyze immediately	0.5 hr/1 hr
Winkler			Titration may be delayed after acidification	8 hr/8 hr
Ozone	G	1.000	Analyze immediately	0.5 hr/—
pH	P.G	—	Analyze immediately	2 hr/2 hr
Phosphate	G(A)	100	For dissolved phosphate filter immediately: refrigerate: freeze at −10 C	48 hr/48 hr
Residue	P.G	—	Refrigerate	7 days/7-14 days
Salinity	G, wax seal	240	Analyze immediately or use wax seal	6 months/—
Silica	P	—	Refrigerate, do not freeze	28 days/28 days
Sludge digester gas	G, gas bottle	—	—	—
Sulfate	P.G	—	Refrigerate	28 days/28 days
Sulfide	P.G	100	Refrigerate: add 4 drops 2*N* zinc acetate/100 mL	28 days/28 days
Taste	G	500	Analyze as soon as possible: refrigerate	24 hr/—
Temperature	P.G	—	Analyze immediately	—/—
Turbidity	P.G	—	Analyze same day: store in dark up to 24 hr	24 hr/48 hr

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*See text for additional details. For determinations not listed, use glass or plastic containers; preferably refrigerate during storage and analyze as soon as possible. Refrigerate = storage at 4 C, in the dark. P = plastic (polyethylene or equivalent); G = glass; G(A) or P(A) = rinsed with 1 + 1 HNO_3; G(B) = glass, borosilicate. G(S) = glass, rinsed with organic solvents.

†Environmental Protection Agency, Proposed Rules, *Federal Register* 44: No. 244, Dec. 18, 1979.

WATER SAMPLING METHODOLOGY

Preparing a Temperature Profile

1. The thermistor (temperature probe) is lowered into the water until it is just immersed. After the probe equilibrates for a short period (5-10 seconds), read the scale and record the reading in degrees centigrade. The surface reading corresponds to a depth (z) of zero.

2. Lower the probe slowly into the water column, stopping to make temperature readings at 0.5 meter intervals. Record these readings on the lake data sheet.

3. If there is a thermocline, it will be noticeable as the region of rapid temperature changes with depth.

4. Continue readings until the probe hits the bottom, usually detected when then probe line becomes slack (i.e., does not hang straight down).

5. Retrieve the line and thermistor probe and wind up the line.

6. The thermal profile can be graphed by plotting temperature on the X-axis and depth on the negative Y-axis. Plot the data on the back of the lake data sheet and indicate possible limits of the epilimnion, hypolimnion and metalimnion.

Taking a Secchi Disk Transparency Reading

1. These readings are best made when the sun is at a high angle, so avoid early morning and late afternoon when sun angle is low.

2. A 20 cm (8") Secchi disk secured by measured line is lowered into the water on the shady side of the boat.

3. The disk is lowered until it is lost to view from the observer, and the depth of this disappearance is noted.

4. The observer retrieves the line until the disk is once again visible, and the corresponding depth recorded.

5. The Secchi disk transparency (SDT) depth is the average of the two measurements. The SDT value can be entered in the lake data sheet, making sure to denote whether the measurement is in feet or the preferred meters.

6. Estimate the limits of the photic zone in Long Pond, knowing that it is between 2 to 3 x the SDT.

Collection of Water

1. Water for chemical analysis is often collected at several depths at any one lake station. If the lake is stratified, this should include a sample from the epilimnion, hypolimnion, and metalimnion layers.

2. Water from the upper layers can be simply collected by holding a bottle several inches under the surface. The other samples will require use of a Scott or Van Dorn water sampler.

3. When sampling from the bottom waters, try not to actually hit the bottom with the sampler. This stirs up a lot of sediments which can contaminate the sample and bias the results. Position the water sampler about 0.5 meters from the bottom to get a good sample.

4. Collection of the metalimnetic sample will require examination of the temperature profile to determine which is the most appropriate depth.

Preparing an Oxygen Profile

1. The oxygen electrode probe must be calibrated before the sampling. This is done by adjusting the oxygen reading to 100% saturation for the ambient air temperature. The 100% saturation level can be determined by consulting standard limnological tables.

2. The oxygen probe is lowered into the water in an analogous manner to the temperature probe. Measurements are made every 0.5 meters and recorded in units of milligrams dissolved oxygen per liter (mg/l). Allow the probe to come to an equilibrium after each depth change. Particularly in the hypolimnion, the oxygen reading may continue to drift downwards for some time before stabilizing.

3. Continue readings until the probe hits bottom. If the bottom is soft this may be somewhat difficult to detect. The probe may go into the top

layer of the anaerobic bottom muds and give a false low oxygen reading. Pull probe back until there is tension on the line, allow the reading to stabilize and record.

4. Plot the data on the back of the lake data sheet using the same depth increments as on the thermal profile. On the same graph plot the dissolved oxygen percent saturation as a function of depth.

Sampling of the Plankton

1. Sampling of the plankton involves collection, concentration, preservation and identification. As an example a Wisconsin style tow net will be used to concentrate and collect zooplankton from Long Pond.

2. The zooplankton net is thrown out or "cast" and rapidly towed through a known distance of water determined by the length of the casting line. The water passes through the net leaving the macroscopic animals. Zooplankters may be preserved in a formalin solution, with sugar added to help maintain the body shape.

3. The aperture of the net (sq. ft or m) x the distance of the tow (ft or m) = the volume of water sampled (cu. ft or m). Thus a concentrated sample can be back-calculated to estimate the number of zooplankters per volume of lake water.

Sampling of the Benthos

1. The animals living in the bottom muds are most easily captured with an Ekman benthic dredge.

2. The dredge is lowered with jaws open (be careful in setting this powerful device) and allowed to sink by its own weight into the sediments. A brass "messenger" weight goes down the line to snap the jaws shut.

3. The dredge is retrieved and the overlying water drained off. The sediments are placed in a pail or similar container.

4. The sediments are passed through a standard 500 micron sieve to isolate the macrobenthos component. These animals are collected by forceps and preserved in an ethanolic solution for later identification.

CALCULATING A DISCHARGE (FLOW) MEASUREMENT

1. At the selected stream stretch, measure the width of the stream or distance perpendicular to the flow between the banks or applicable water margins. This should be done at three locations (transects) within 100m of each other.

2. At regular intervals (e.g., 1-2 meters) within each of the three transects, measure the depth of the stream. From the information gathered in Steps #1 and #2, compute the cross-sectional area of the three stream transects.

3. Determine the current velocity for each of the transects. At several locations within the transect (minimum of three) determine velocity with the float method, that is, measure the time needed for the downstream passage of a floating object over a known distance (e.g., 10 meters). Repeat the measurements several times and calculate velocity (e.g., meters/second).

4. Alternatively, velocity can be determined with a current meter (e.g., pygmy-type current meter from Teledyne-Gurley). This is a hydraulic analogue of a wind anemometer, where the rate of revolution of spinning cups translates, in this case, to water velocity. As with the float method it is important to take several replicated measurements at various locations across the transect to factor out the influence from individual currents and backeddies.

5. Multiply the cross-sectional area calculated in Step #2 by the velocity determined in Step #3 or #4 to arrive at the corresponding discharge or flow measurement (i.e., area (sq. m) *velocity (m/sec) = flow (cu. m/sec). There should be general agreement with the flow measurements calculated for the three adjoining transects, and an average of the three can be considered representative for the stream at this location.

ESTIMATION OF LAKE VOLUME

1. Determine the surface area (Ao) of the lake or pond through tracing the outline of the lake with a planimeter. The lake shape is generally recorded from a USGS topographic map or a recent aerial photograph. Basin volume is approximated through measuring the area of lake contours at the smallest depth interval possible.
2. Using depth measurements, plot depth contours for the lake or pond.
3. Determine the surface area of each depth contour (Az).
4. Determine the lake volume for each depth interval i.e. surface area of contour x depth interval = volume of depth interval.
5. Add up the volume of each depth interval.

*See Worksheet 2 from the coursebook (enclosed in field manual) for an example of a lake volume calculation.

WORKSHEET 2 - EXAMPLE OF LAKE VOLUME CALCULATION

ALDEN POND, LUDLOW, MA - VOLUME CALCULATIONS

DEPTH (ft)	SURFACE AREA A_o (ft^2)	PERCENT A_o	AREA AT DEPTH A_z	LAYER (ft)	VOLUME (ft^3)
0-3	162,914	0.85	138,477	3	415,431
3-6	162,914	0.58	94,490	3	283,470
6-9	162,914	0.24	39,099	3	117,298
9-11.5	162,914	0.03	4,887	2.5	12,219
					824,418

824,418 ft^3 = 19.02 acre-ft.

WORKSHEET 2 - EXAMPLE OF FLUSHING RATE AND DETENTION TIME CALCULATION

NASHAWANNUCK POND, EASTHAMPTON, MA - FLUSHING RATE

Assume that annual inflow equals flow through the system = 23.4 cu.m/min.
since 1 cfs = 1.7 cu.m/min this is equivalent to 23.4/1.7 or 13.8 cfs

Mean annual inflow = 23.4 cu.m/min X 60 min/hr x 24 hr/day x 365 day/yr
or 12,299,040 cu.m/yr

Assume lake volume equals 234,890 cu.m

$$\text{Flushing rate} = \frac{\text{inflow total}}{\text{Volume}} = \frac{12{,}299{,}040 \text{ cu.m/yr}}{234{,}890 \text{ cu.m}} = \underline{52.4 \text{ flushings per year}}$$

NASHAWANNUCK POND, EASTHAMPTON, MA - RESIDENCE OR DETENTION TIME

Assume that outflow equals flow through the system = 23.4 cu.m/min.

Assume lake volume equals 234,890 cu.m

Mean annual output = 12,299,040 cu.m/yr

$$\frac{234{,}890 \text{ cu.m}}{12{,}299{,}040 \text{ cu.m/yr}} = 0.019 \text{ yr} \times 365 \text{ day/yr} = \underline{7 \text{ days}}$$

ESTIMATION OF ANNUAL INFLOW CALCULATIONS

There are several methods available to approximate annual inflow to a lake. The following is a description of two simple methods which may be used:

Unit Watershed Method

1. Calculate area of the lake or pond and its watershed. This is typically done through the use of a planimeter.

2. Estimate annual inflow for the lake. Inflow estimate = (k) x watershed and lake area (sq. mi.). Yield coefficients (k) may be found in the following document:

   Weiss, L.A., 1983. Evaluation and Design of a Streamflow--Data Network for Connecticut. USGS and CT. DEP. Connecticut Water Resources Bulletin #36.

   The typical yield coefficient for Massachusetts is 1.5. However, this will vary depending upon watershed characteristics.

Runoff Estimate Method

1. Determine the average yearly precipitation through contacting the local Soil Conservation Service.

2. Estimate the degree of runoff. Runoff estimates may be found in:

   Higgins and Colonell, 1971. Hydrologic Factors in the Determination of Water Yields. Water Resources Research Center. Amherst, MA.

3. Estimate direct precipitation on the lake or pond
   = precipitation (ft/yr) x lake area (ft) = ______ ft^3/yr.

4. Estimate evaporative losses for the lake or pond. Approximately 50% of the precipitation rate falling on a lake surface would be lost through evapotranspiration

5. Calculate flow estimate

   = (runoff) + (direct precipitation) - (evaporation).

*See Worksheet 1 for an example of annual inflow calculations.

ESTIMATION OF FLUSHING RATE AND DETENTION TIME

1. Determine annual inflow (Q) from feeder streams to a lake to determine the degree of circulation which will occur. See Worksheet #1 of coursebook.

2. Calculate total mean annual inflow from feeder streams.

3. Determine lake volume (see "Estimation of Lake Volume" in Field Manual).

4. Flushing Rate $= \dfrac{\text{inflow total}}{\text{volume}}$.

5. Calculate mean annual output. Assume that outflow equals flow through the system.

6. Calculate mean annual output.

7. Residence or flushing time $= \dfrac{\text{lake volume}}{\text{mean annual output}}$.

8. Typical flushing rates in Massachusetts are 3-6 months.

*See Worksheet #2 for an example of flushing rate and detention time calculation.

WORKSHEET 1 - EXAMPLE OF ANNUAL INFLOW CALCULATIONS

HYDROLOGIC CALCULATIONS FOR MAMANASCO LAKE, RIDGEFIELD, CT

1.) Unit Watershed Area Method.

a.) Watershed Area + Lake: 537 ac + 96 ac = 0.99 sq. mi.

b.) Use yield coefficients (Weiss, 1983) with watershed area.

Yield estimate = 1.58 cfs/sq. mi. x watershed areas (sq. mi.)

Mamanasco estimate = 1.58 cfs/sq. mi. x 0.99 sq. mi. = 1.56 cfs

2.) Runoff Estimate Method.

a.) Assume that certain portion of the precipitation is runoff that flows into surface tributaries. Add direct precipitation to lake and subtract evaporative loss. The runoff estimates used are from Higgins and Colonell (1971), and the average yearly precipitation is 47.1" or 3.93 ft/yr; as measured at Danbury, CT (SCS, 1981).

b.) High runoff range = 2.61 ft/yr x 537 ac = $5.450\ 10^7\ ft^3/yr$.

Low runoff range = 1.67 ft/yr x 537 ac = $3.906\ 10^7\ ft^3/yr$.

c.) Direct precipitation on Mamanasco Lake:

3.93 ft/yr x 96 ac = $1.643\ 10^7\ ft^3/yr$.

d.) Evaporation losses from Mamanasco Lake:

2.33 ft/yr x 96 ac = $0.974\ 10^7\ ft^3/yr$.

e.) Calculations :

54,500,000 + 16,430,000 - 9,740,000 = 61,190,000 ft^3/yr.

39,060,000 + 16,430,000 - 9,740,000 = 45,750,200 ft^3/yr.

f.) Range of flow estimates = 1.45 - 1.94 cfs

REFERENCES

Higgins G.R. and J.M. Colonell. 1971. Hydrologic Factors in the Determination of Water Yields. Water Resources Research Center. Amherst, MA.

Soil Conservation Service. 1981. Soil Survey of Fairfield County, Connecticut. USDA and the Connecticut Agricultural Experimental Station, Storrs, CT.

Weiss, L.A. 1983. Evaluation and Design of a Streamflow - Data Network for Connecticut. USGS and CT DEP. Connecticut Water Resources Bulletin #36.

VEGETATIVE ASSESSMENT

Vegetative assessment is typically conducted to describe the types and concentrations of in-lake vegetation and bordering wetlands. In-lake vegetation typically includes algae and macrophyte species. Further description of wetland vegetation, and an aquatic plant key is enclosed

BORDERING VEGETATED WETLANDS DEFINED

The freshwater inland wetland areas that the Massachusetts Wetlands Protection Act protects include banks, land subject to flooding, land under water bodies and waterways, and vegetated wetlands that border water bodies (bordering vegetated wetlands and marshes) and specifies typical indicator plant species for each. The following definitions excerpted from the Act and the regulations should be used to apply the law to field observation.

Freshwater wetlands: (MGL C. 131, s.40)

> "The term 'freshwater wetlands', as used in this section; shall mean wet meadows, marshes, swamps, bogs, areas where groundwater, flowing or standing surface water or ice provides a significant part of the supporting substrate for a plant community for at least five months of the year; emergent and submergent plant communities in inland waters; that portion of any bank which touches any inland waters."

Bordering Vegetated Wetlands: [310 CMR 10.55(2) (a)]

> "Bordering Vegetated Wetlands are freshwater wetlands which border on creeks, rivers, streams, ponds and lakes. The types of freshwater wetlands are wet meadows, marshes, swamps and bogs. They are areas where topography is low and flat, and where the soils are annually saturated. The ground and surface water regime and the vegetational community which occur in each type of freshwater wetland are specified in the Act."

- Bogs: (C. 131, s.40)
  ". . . areas where standing or slowly running water is near or at the surface during a normal growing season and where a vegetational community has a significant portion of the ground or water surface covered with sphagnum moss (Sphagnum) . . ."

- Swamps: (C. 131, s.40)
  ". . . areas where ground water is at or near the surface of the ground for a significant part of the growing season or where runoff water from surface drainage frequently collects above the soil surface . . ."

- Wet Meadows: (C.131, s.40)
  ". . . where ground water is at the surface for a significant part of the growing season and near the surface throughout the year and where a significant part of the vegetated community is composed of various grasses, sedges and rushes; . . ."

- Marshes: (C.131, s.40)
  ". . . areas where a vegetational community exists in standing or running water during the growing season . . ."

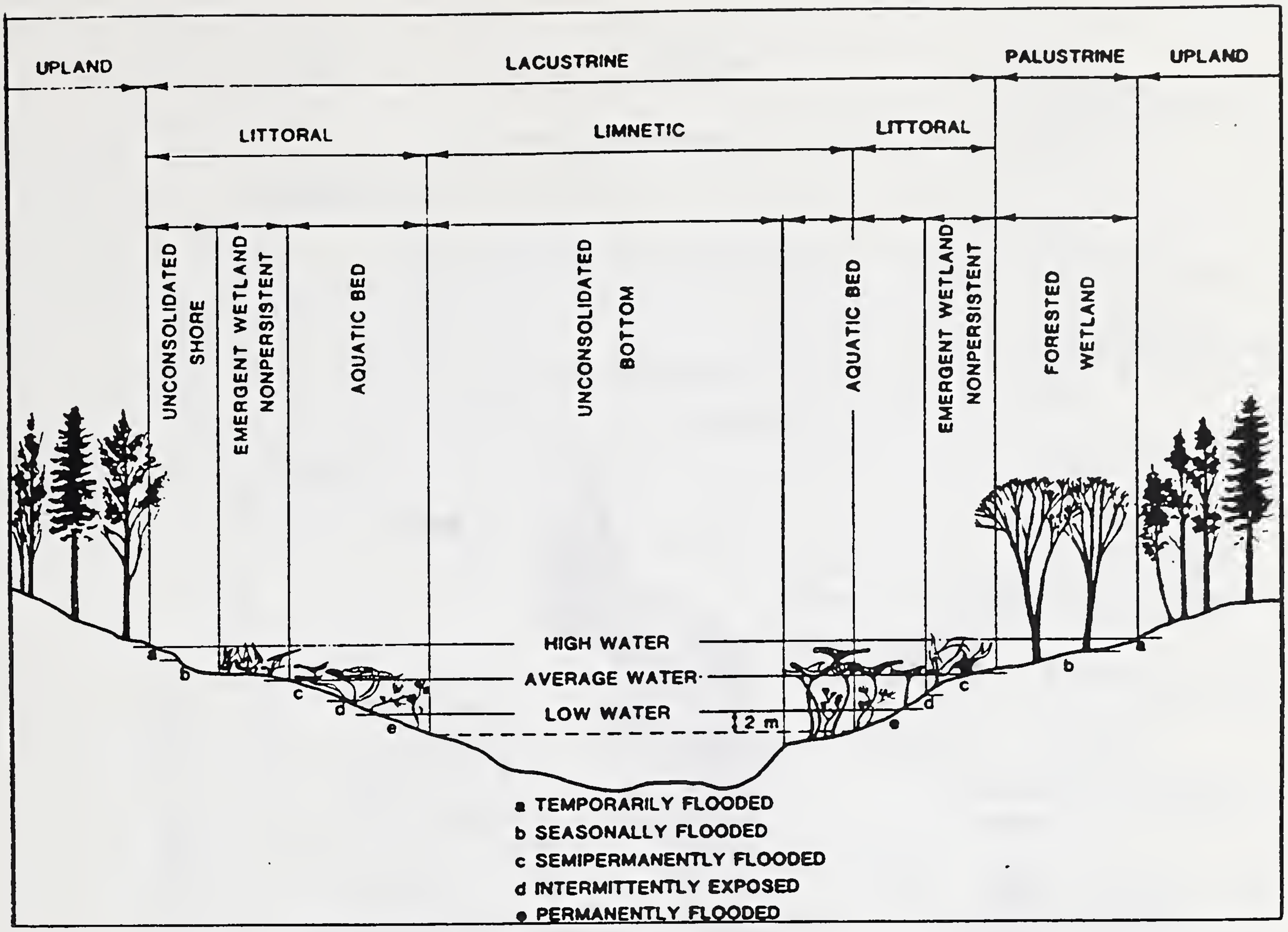


Fig. 5. Distinguishing features and examples of habitats in the Lacustrine System.

Lacustrine System

Definition. The Lacustrine System (Fig. 5) includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water. Lacustrine waters may be tidal or nontidal, but ocean-derived salinity is always less than 0.5‰.

Limits. The Lacustrine System is bounded by upland or by wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens. Lacustrine Systems formed by damming a river channel are bounded by a contour approximating the normal spillway elevation or normal pool elevation, except where Palustrine wetlands extend lakeward of that boundary. Where a river enters a lake, the extension of the Lacustrine shoreline forms the Riverine-Lacustrine boundary.

Description. The Lacustrine System includes permanently flooded lakes and reservoirs (e.g., Lake Superior), intermittent lakes (e.g., playa lakes), and tidal lakes with ocean-derived salinities below 0.5‰ (e.g., Grand Lake, Louisiana). Typically, there are extensive areas of deep water and there is considerable wave action. Islands of Palustrine wetland may lie within the boundaries of the Lacustrine System.

Subsystems.

-*Limnetic.*—All deepwater habitats within the Lacustrine System; many small Lacustrine Systems have no Limnetic Subsystem.

-*Littoral.*—All wetland habitats in the Lacustrine System. Extends from the shoreward boundary of the system to a depth of 2 m (6.6 feet) below low water or to the maximum extent of nonpersistent emergents, if these grow at depths greater than 2 m.

Classes. Rock Bottom, Unconsolidated Bottom, Aquatic Bed, Rocky Shore, Unconsolidated Shore, and Emergent Wetland (nonpersistent).

Cowardin, Lewis M., Virginia Carter, Francis Golet
and Edward LaRoe, 1979, Classification of
Wetlands and Deepwater Habitats of the
United States, U. S. Department of the Interior,
Fish and WIldlife Service

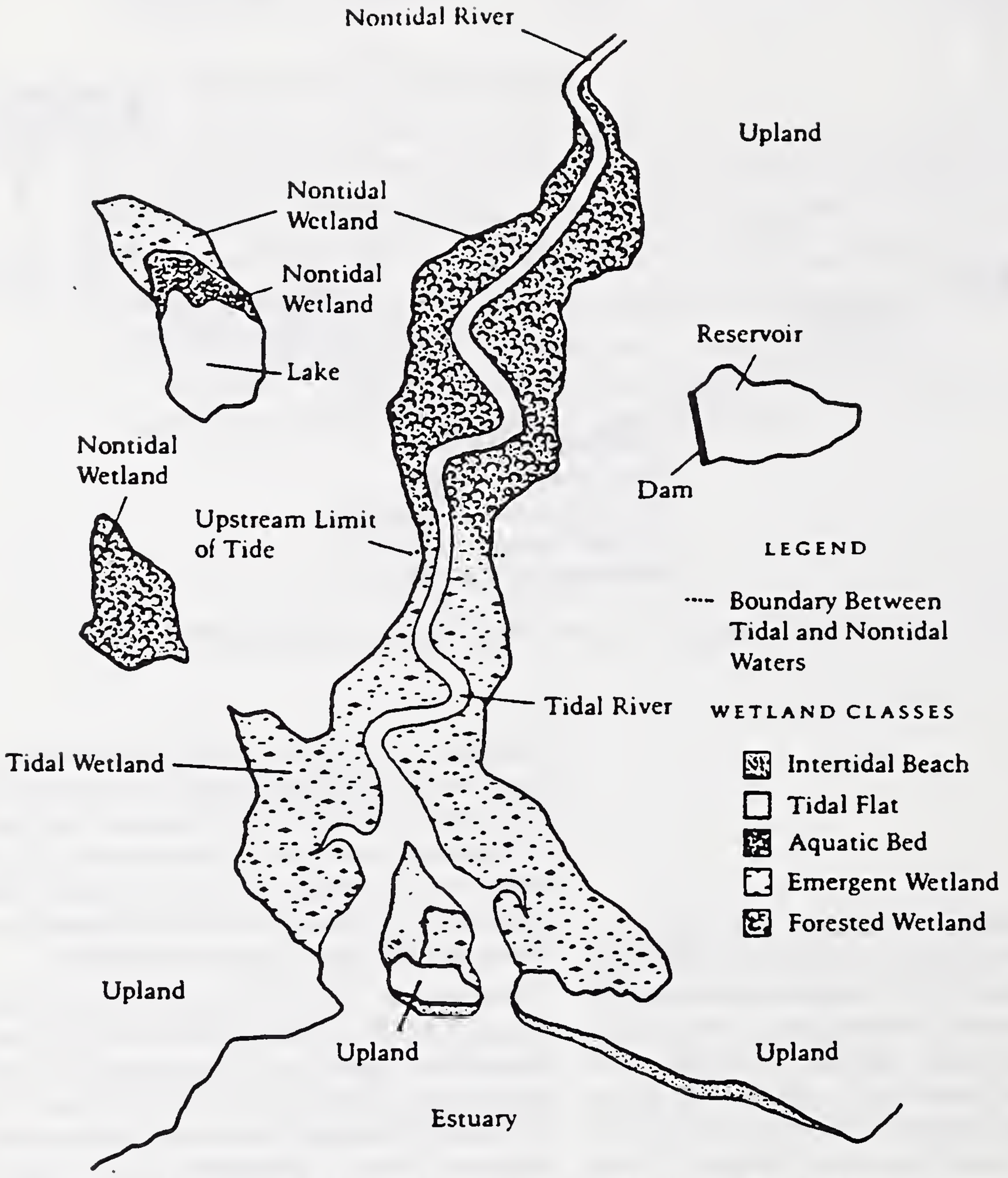


Figure 1. General locations of tidal and nontidal wetlands in relation to deepwater habitats and upland. (Source: adapted from *Wetlands of Delaware*, Tiner 1985)

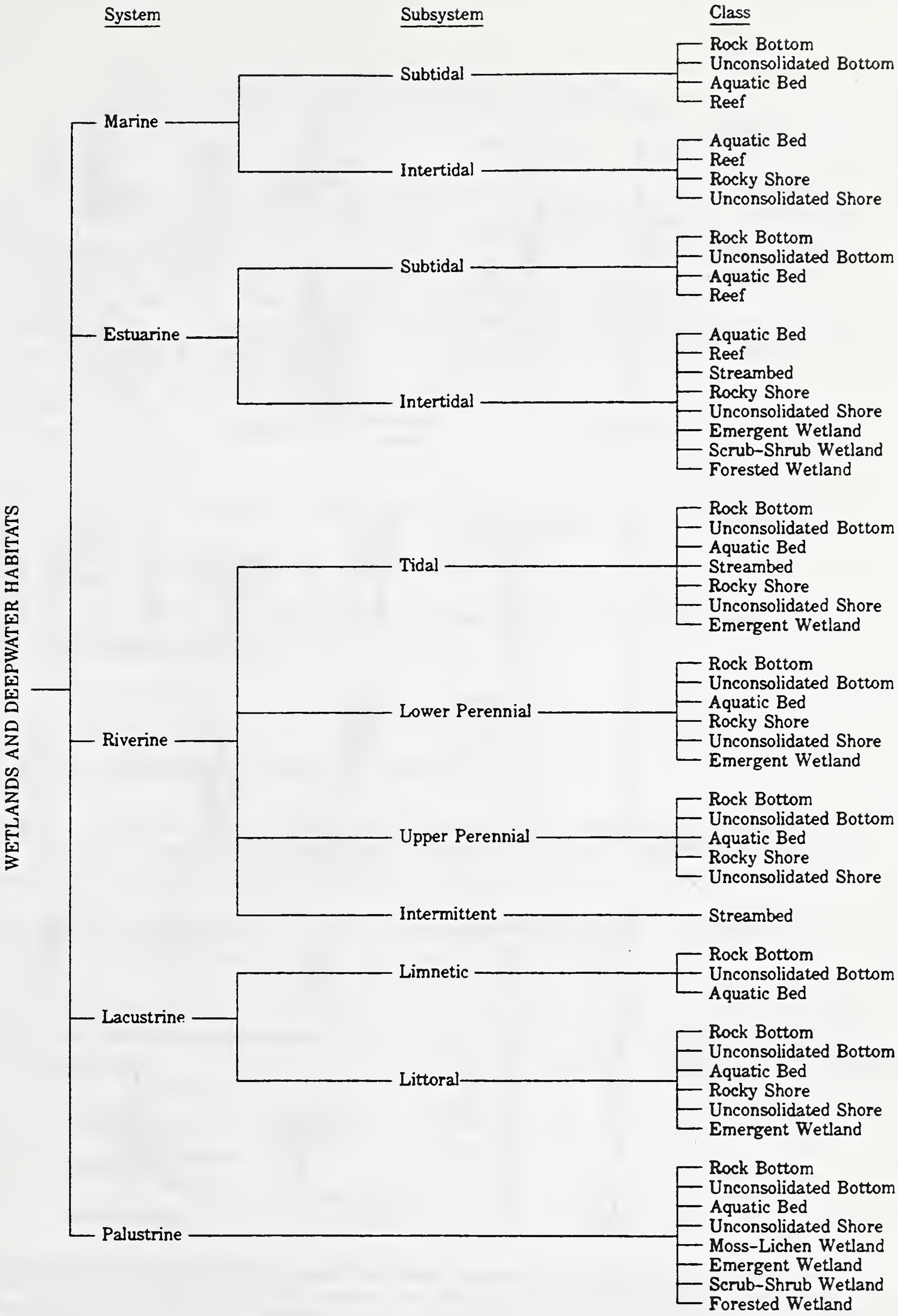


Fig. 1. Classification hierarchy of wetlands and deepwater habitats, showing Systems, Subsystems, and Classes. The Palustrine System does not include deepwater habitats.

Cowardin, Lewis M., Virginia Carter, Francis Golet and Edward LaRoe, 1979, Classification of Wetlands and Deepwater Habitats of the United States, U. S. Department of the Interior, Fish and WIldlife Service

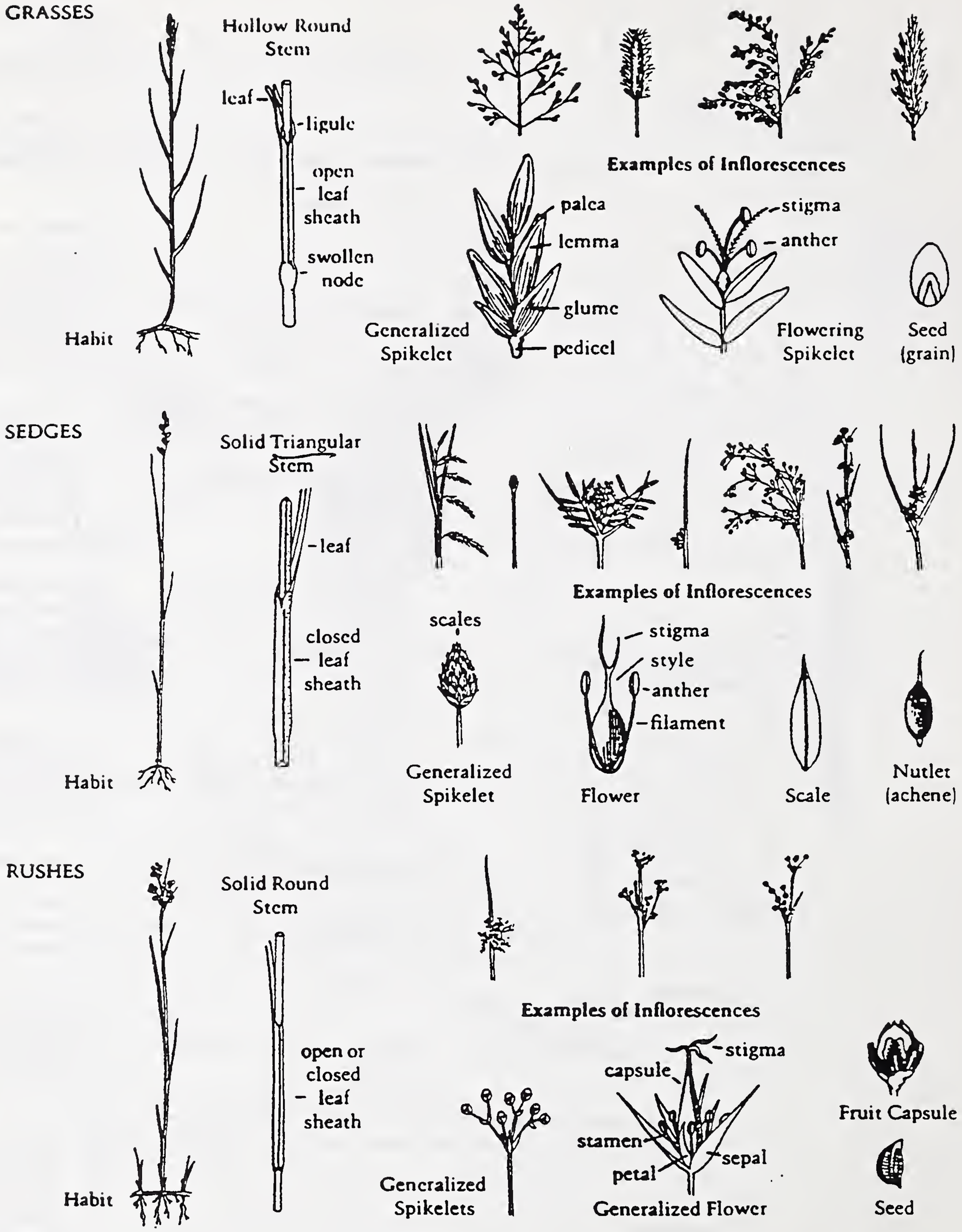


Figure 4. Distinguishing characteristics of grasses, sedges, and rushes. (Source: modified from *A Field Guide to Coastal Wetland Plants of the Northeastern United States*. Tiner 1987) Grasses have hollow round stems with swollen nodes, open leaf sheaths, and grainlike seeds covered by two papery scales. Sedges usually have solid triangular stems lacking nodes, closed leaf sheaths, and nutlets covered by one papery scale. Rushes have solid round stems lacking nodes, true flowers with six "petals," and fruit capsules bearing numerous small seeds.

KEY TO SOME COMMON AQUATIC PLANTS
(modified from Mackenthum et al., 1964)

A simplified key to aid in the identification of common plant groups. To use the key, select the proper habit grouping and read the description in the first couplet. The description that best fits the unknown specimen will indicate either the plant group or genus to which the specimen belongs or an additional couplet, in which case the process is repeated until the description for a particular plant or genus which best fits the unknown specimen is reached.

Habit Groupings:

A. Plants floating on the water surface

B. Plants submerged beneath water surface

C. Plants erect and emergent; rooted to the substratum and extending upward out of the water.

KEY

A. PLANTS FLOATING ON THE WATER SURFACE.

1a. A lobed or regularly forked plant body, usually small in size, roots usually suspended free in the water, with no connection to the lake bottom; capable of drifting 2

1b. Floating-leafed plants with leaves attached to the bottom by a bare unbranched stem of varying length 6

2a. Plants consisting of forked, or cross-shaped, long-stalked segments, floating below the surface, often many entangle to form clumps .... Star Duckweed, *Lemna trisulca*

2b. Plants rounded, not stalked 3

3a. Plants with roots 4

3b. Plants without roots 5

4a. Plants red on the lower surface, each joint with two or more roots .... Big Duckweed, *Spirodela polyrhiza*

4b. Plants green on the lower surface, each joint with one root .... Duckweed, *Lemna*

5a. Plants globular, pea green, the size of a pinhead .... Watermeal, Wolffia

5b. Plants thin, sickle-shaped or elongated (rare in NE) .... Mud-midget, Wolfiella

6a. Stem attached to middle of leaf 7

6b. Stem attached at the summit of deep notch in the leaf ... 8

7a. Leaves oval, not more than 3 inches wide, with supple stem attached to middle of the leaf .... Watershield, Brasenia schreberi

7b. Circular leaf with a long, fairly rigid stem attached to the middle of the leaf, leaves 6 inches or more wide sometimes supported by the stem above the water level .... American lotus, Nelumbo

8a. Circular or heart-shaped leaf with the veins radiating from the mid-rib to nearly the margin without forking,; floating yellow flowers .... Yellow Pond Lily, Nuphar

8b. Circular leaf with much-forked veins radiating to the margin, white or pink floating flowers .... White Water Lily, Nymphaea

B. PLANTS SUBMERGED BENEATH THE WATER SURFACE.

1a. Plant body made up of stems bearing whorled, brittle branches, easily snapped with a slight pressure; plants with a musky odor, no roots, often with a limy encrustation .... Green Algae, Muskgrass, Chara

1b. Plant structure similar to 1a., but with supple branches, no musky odor, and no limy encrustation .... Green Algae, Nitella

1c. Plant body not brittle and structure otherwise 2

2a. Submerged leaves bearing small bladders, leaves irregularly forked .... Bladderwort, Utricularia

2b. Submerged leaves not bearing bladders 3

3a. Submerged leaves compound, made up of narrow segments or leaflets 4

3b. Submerged leaves simple, composed of single narrow blade .7

4a. Submerged leaves with one central axis, leaves feather-like, branched in whorls about the stem, stems usually very lax .... Watermilfoil, Myriophyllum

4b. Submerged leaves irregularly forking 5

5a. Submerged leaves singly and alternately or irregularly borne; leaves manly branched, irregularly forked and appearing as tufts of numerous thread-like projections attached to the center stem ... Water Buttercup, Ranunculus

5b. Submerged leaves borne opposite each other on stem or whorled 6

6a. Leaves stalked, fan-like, extending from opposite sides of the stem; leaflets not toothed ....Fanwort, Cabomba

6b. Stems with whorls of stiff, forked leaves; leaflets with toothed or serrated margins (small barbs) on one side; plant without true roots .... Coontail, Ceratophyllum

7a. Submerged leaves long and ribbon-like; at least 1/10 inch wide 8

7b. Submerged leaves not ribbon-like, often thread like but if wider than 1/10 inch, less than 1 inch long 18

8a. Leaves scattered along the stem 9

8b. Leaves all borne from one point 18

9a. Leaves with mid-ribs evident when held against bright light; many species with great diversity in leaf forms .... Pondweed, Potamogeton

9b. Leaves without mid-ribs evident when held against bright light .... Water Star Grass, Zosterella

10a. Plants with both floating and submerged leaves, the floating leaves with expanded blades and differing from those submerged 11

10b. Plants with all leaves similar and submerged 14

11a. Floating leaves, heart-shaped at the base, 1 to 4 inches long, waxy in appearance .... Floating-leafed Pondweed, Potamogeton natans

11b. Floating leaves rounded at the base 12

12a. Floating leaves with 30 to 50 nerves; submerged leaves about three times long as broad .... Large-leafed Pondweed, *Potamogeton amplifolius*

12b. Floating leaves with less than 30 nerves 13

13a. Upper submerged leaves with long stalks .... Pondweed, *Potamogeton nodosus*

13b. Submerged leaves not as above, but with an abrupt awlshaped tip .... Pondweed, *Potamogeton illinoensis*

14a. Margins of the thin leaves crimpled and toothed, the marginal serrations visible to the naked eye .... Curly-leafed Pondweed, *Potamogeton crispus*

14b. Margins of leaves not visibly toothed 15

15a. Leaves minute toothed on the margins, visible when magnified; leaves extending stiffly in opposite directions so that whole plant appears flat; only midvein prominent .... Robbins Pondweed, *Potamogeton robbinsii*

15b. Not as above 16

16a. Stems much flattened and winged, about as wide as the leaves, leaves 1/12 to 1/5 inched wide .... Flat-stemmed Pondweed, *Potamogeton zosteriformis*

16b. Leaves threadlike, long, rounded, and slender, rarely exceeding 1/10 inch wide, oriented into a lax, diffuse, branched spray. The bunched appearance of the the threadlike rounded leaves as they float in the water is characteristic ...... Sago Pondweed, *Potamogeton pectinatus*

17a. Leaves very long and ribbonlike; when examined with hand lens; showing a central dense zone and a peripheral less dense zone; flowers borne on a long stem which forms a spiral after fertilization .... Wild Celery, *Vallisneria*

17b. Leaves when examined with hand lens, not showing zones as above .... Water Plantains *Alismataceae*

18a. Leaves opposite, all leaves elongated and narrow, many times longer than broad, and enlarged or dilated at base. Bunches of smaller leaves near the leaf base .... Bushy Pondweed, *Najas*

18b. Leaves whorled, usually 3 in each whorl (sometimes 4) .... Waterweed, *Elodea* (= *Anacharis*)

C. PLANTS ERECT AND EMERGENT; ROOTED TO THE SUBSTRATUM AND EXTENDING OUT OF THE WATER.

1a. Leaves more than 10 times as long as broad 2

1b. Leaves less than 10 times as long as broad 9

2a. Base of stem triangular in cross-section, the three angles in some cases so rounded as to make stem appear round............. 3

2b. Base of stem not triangular 5

3a. Three cornered seeds, usually straw colored, enclosed within a loose elongated sac; a low-growing grass-like plant .... Sedge, *Carex*

3b. Seeds not enclosed within a loose, elongated sac.......... 4

4a. A single flow or seed-bearing structure on the tip of the stem .... Spike Rush, *Eleocharis*

4b. Stem with one or more leaves extending beyond the spike or seed-bearing structure .... Bulrush, *Scirpus*

5a. Leaf with a collarlike appendage, membranous or composed of hairs at the junction of the leaf blade and that part of the leaf that is wrapped around the stem 6

5b. Leaf without collarlike appendage mentioned above 8

6a. Seed or flowering-bearing structure composed of scales with fringed margins and overlapping in a single row .... Cut Grass, *Leersia*

6b. Flowering-bearing structure not as above 7

7a. Flowering-heads composed of small seeds with long silky hairs, appearing as a silky mass. The rootstocks are stout, and plants are 6 to 12 feet tall .... Reed Grass, *Phragmites*

7b. Flowering part of plant much branched, but not as closely packed as *Phragmites*. Seeds much larger, about 3/4 inch long. Plants with short roots, easily pulled up .... Wild Rice, *Zizania*

8a. Flowers borne in closely packed cylindrical spikes, seeds very small .... Cattail, *Typha*

8b. Flowers in spherical heads, seeds larger, up to size of corn kernel; leaves shallowly and broadly triangular in cross-section .... Burreed, *Sparganium*

9a. Leaves arising at intervals along stem 10

9b. Leaves arising at base of plant 11

10a. Plants with jointed stems, swollen at the joints, or with creeping rootstocks; stems with alternate, simple leaves .... Smartweed, *Polygonum*

10b. Stems prostrate or creeping, branched, and often jointed and rooted at the joints; leaves opposite; spreading plant, often forming floating mats over extensive water areas .... Alligatorweed, *Alternanthera*

11a. Fleshy or tuber-bearing rootstocks and rosettes of sheathing basal leaves; leaves variable; some kinds arrowhead shaped .... Duck Potato, *Sagittaria*

11b. Not as above, floating plants 12

12a. Plants floating with fibrous, branched roots and rosettes of stalked leaves, the leaf stalks often inflated and bladder-like. .... Waterhyacinth, *Eichhornia*

12b. Plants with floating rosettes of stalked leaves, commonly several rosettes produced on branches of the same plant at the end of flexible, cardlike, sparsely-branched submerged stems; plant thrives at the depths of 2 to 5 feet and favors muddy bottoms with high organic content .... Waterchesnut, *Trapa*

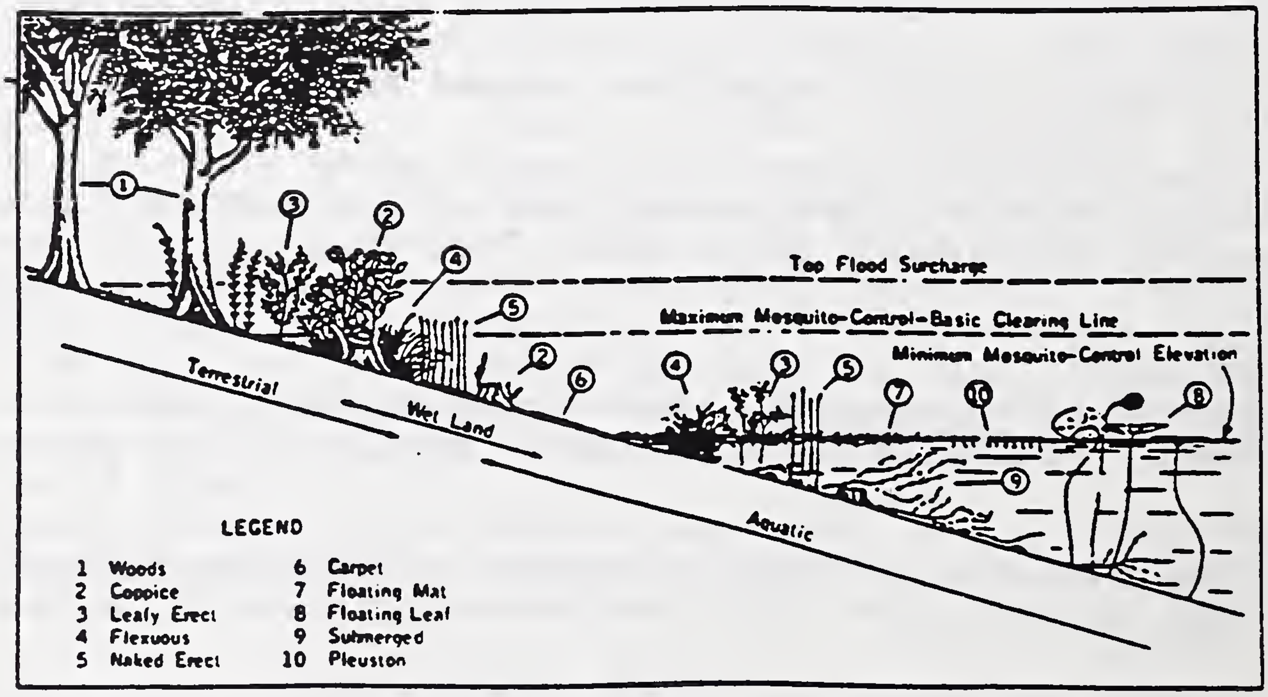
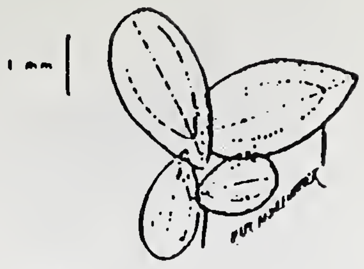
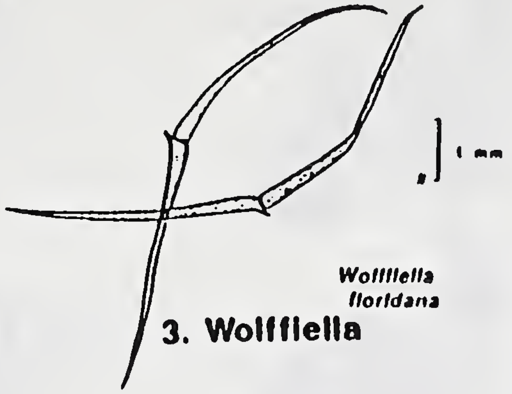


Figure . Generalized contour distribution of basic plant types on the shore line of a main-river reservoir.

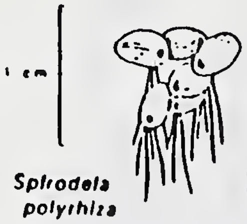
SOURCE: Mackenthum et al., 1964



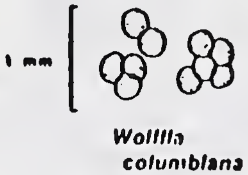
1. Lemna



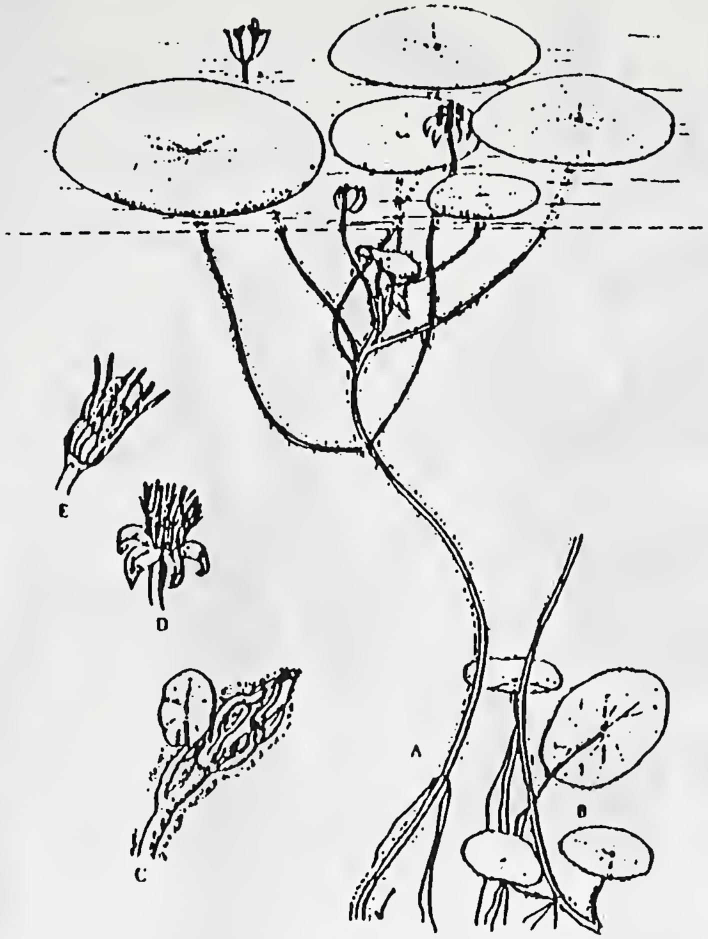
3. Wolffiella



2. Spirodela

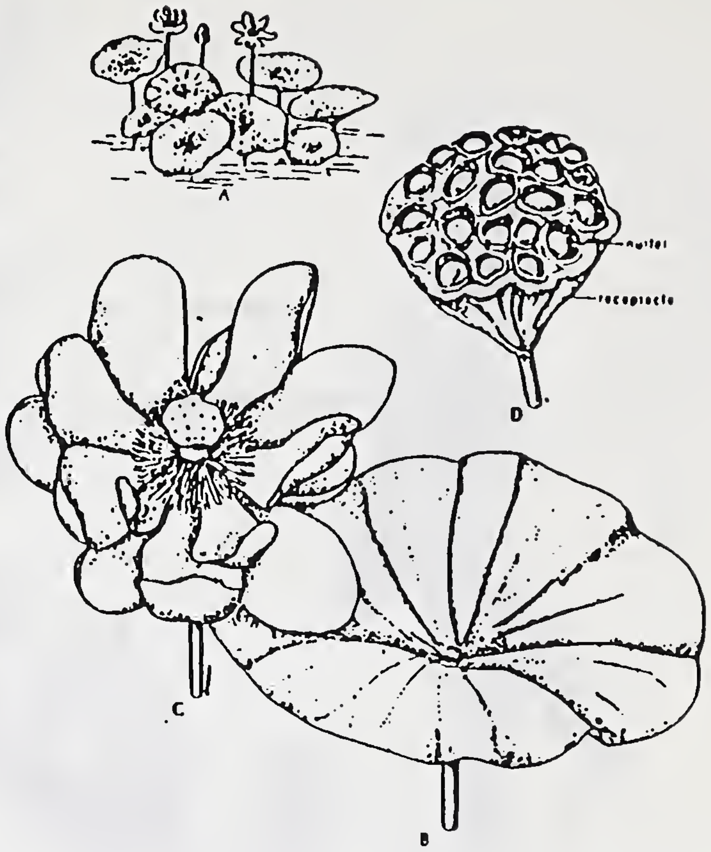


4. Wolffia



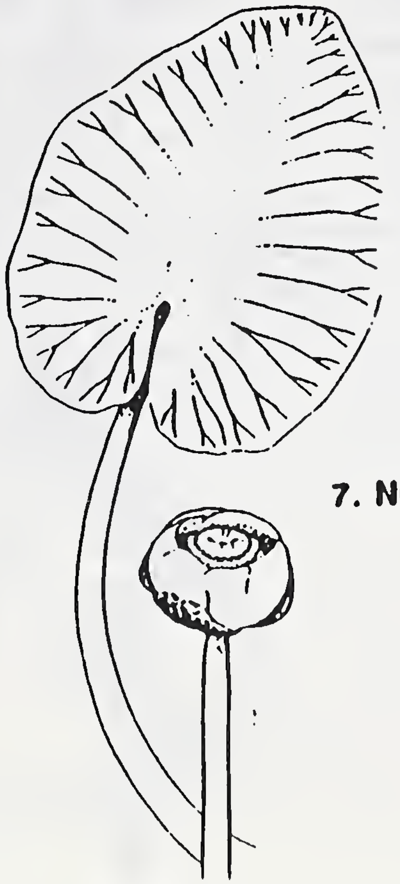
Brasenia schreberi: A. habit × ½. B. submersed leaves of young plant × ¼. C. winter bud with thick mucilaginous coating × ¼. D. flower × 1. E. section of flower showing separate carpels × 1½.

5. Brasenia

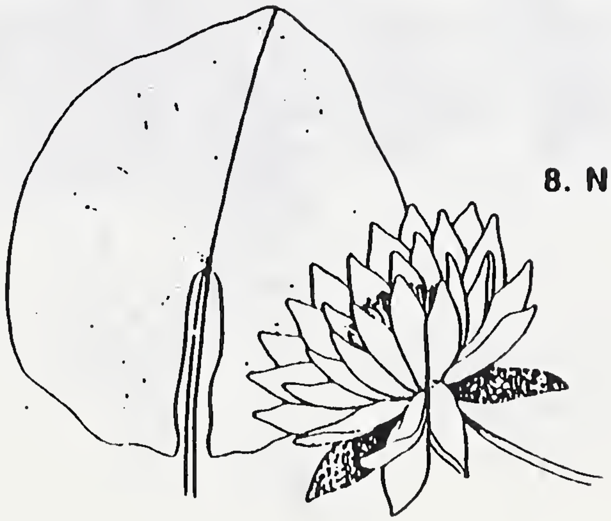


Nelumbo lutea: A. habit. B. leaf × ¼. C. flower × ½. D. woody receptacle with fruits × ½.

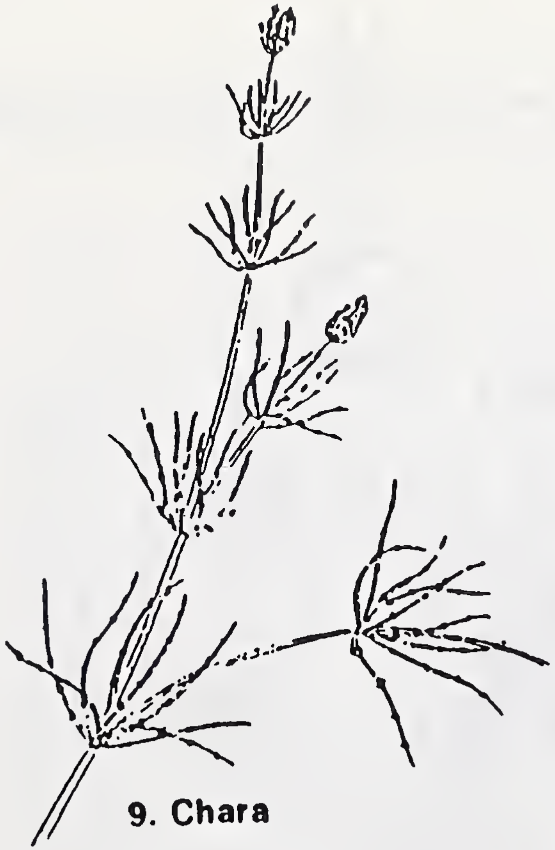
6. Nelumbo



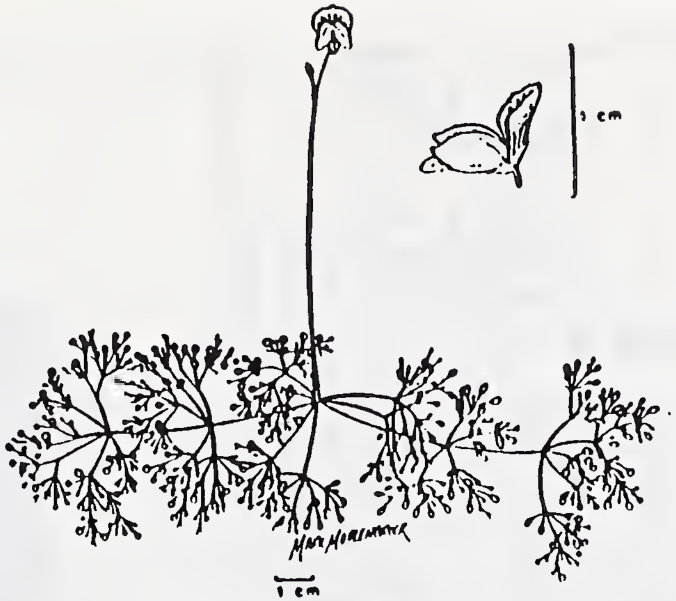
7. Nuphar



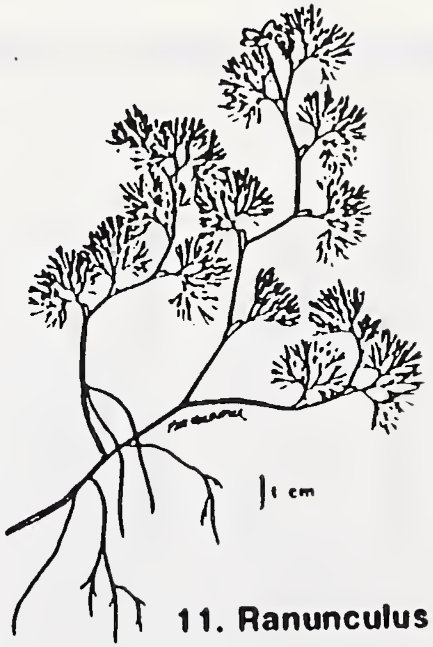
8. Nymphaea



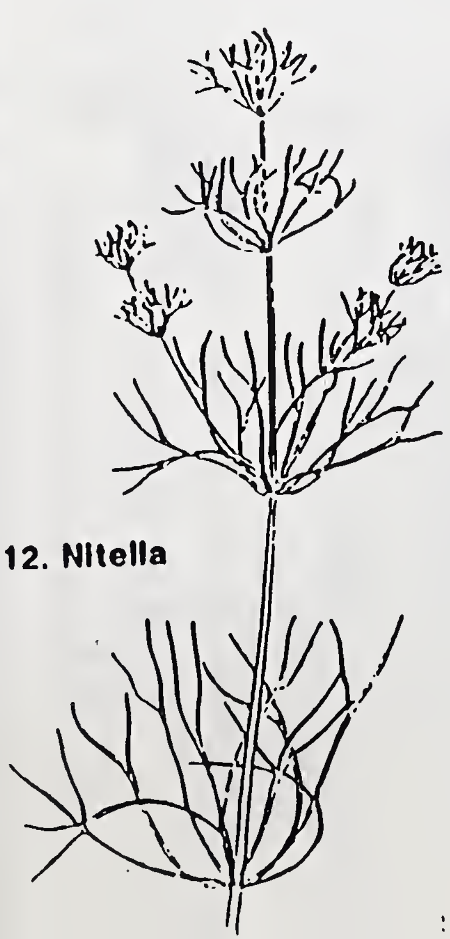
9. Chara



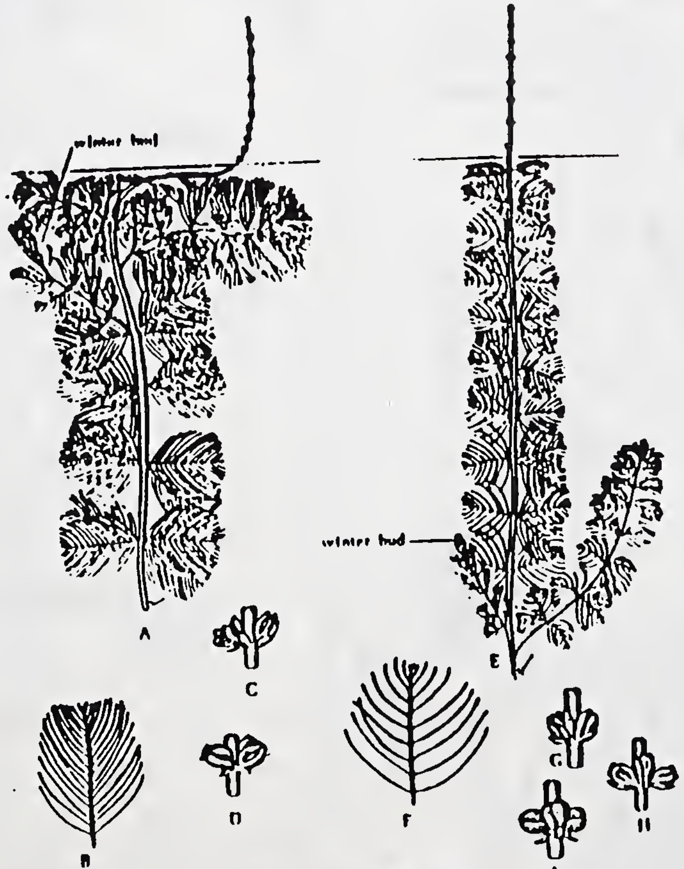
10. Utricularia



11. Ranunculus

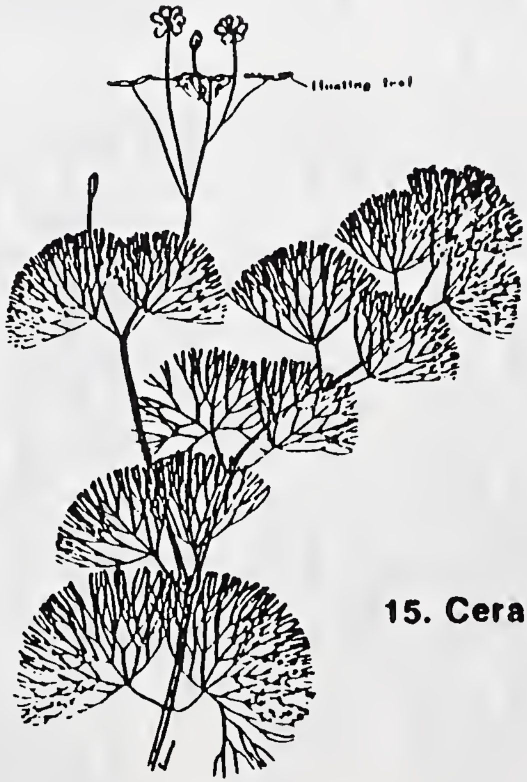


12. Nitella



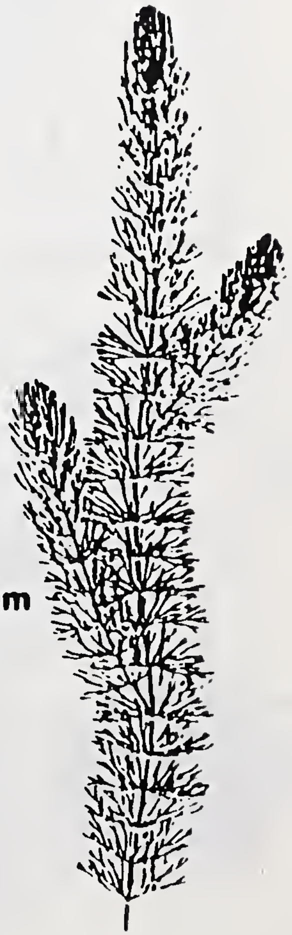
13. Myriophyllum

Myriophyllum spicatum: A. habit of submersed form with emergent inflorescence, × ¼. B. leaf, × 1. C. flowers, × 2. D. fruits, × 2.
Myriophyllum exalbescens: E. habit of submersed form with emergent inflorescence, × ¼. F. leaf, × 1. G. flowers, × 2. H. immature fruit, × 2 I. mature fruit, × 2.

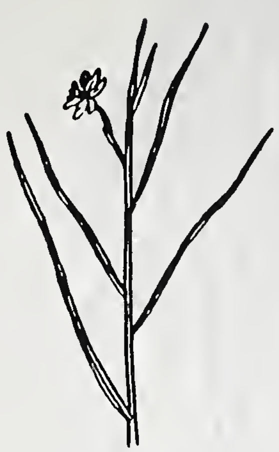


14. Cabomba

Cabomba caroliniana: habit

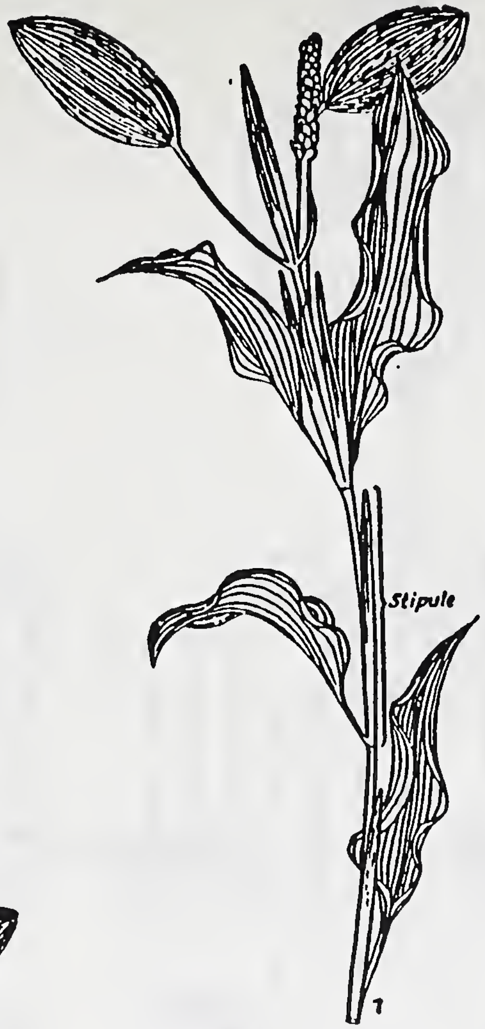


15. Ceratophyllum



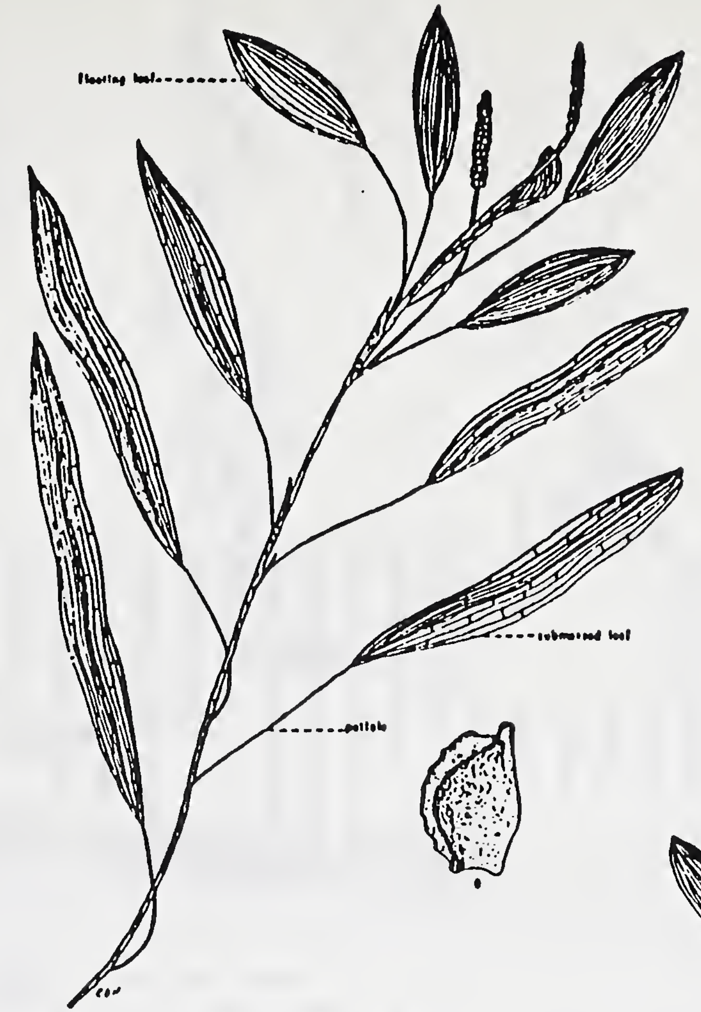
Zosterella dubia

16. Zosterella



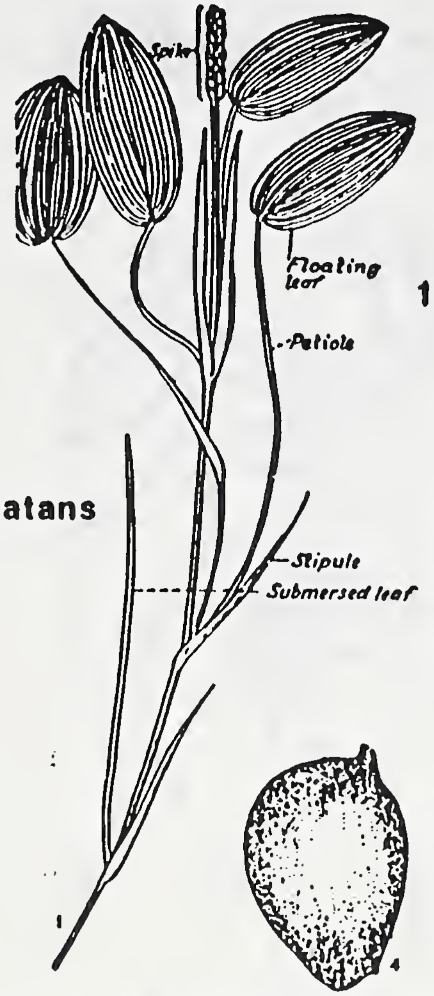
P. amplifolius: 7. Upper part of plant, × ¼.

17. Potamogeton amplifolius



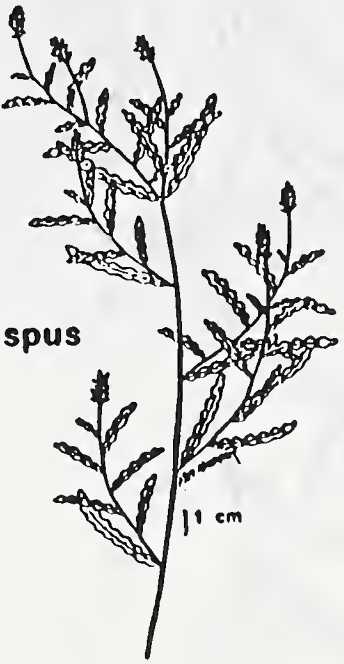
Potamogeton nodosus: A. upper portion of plant. B. fruit.

18. P. nodosus

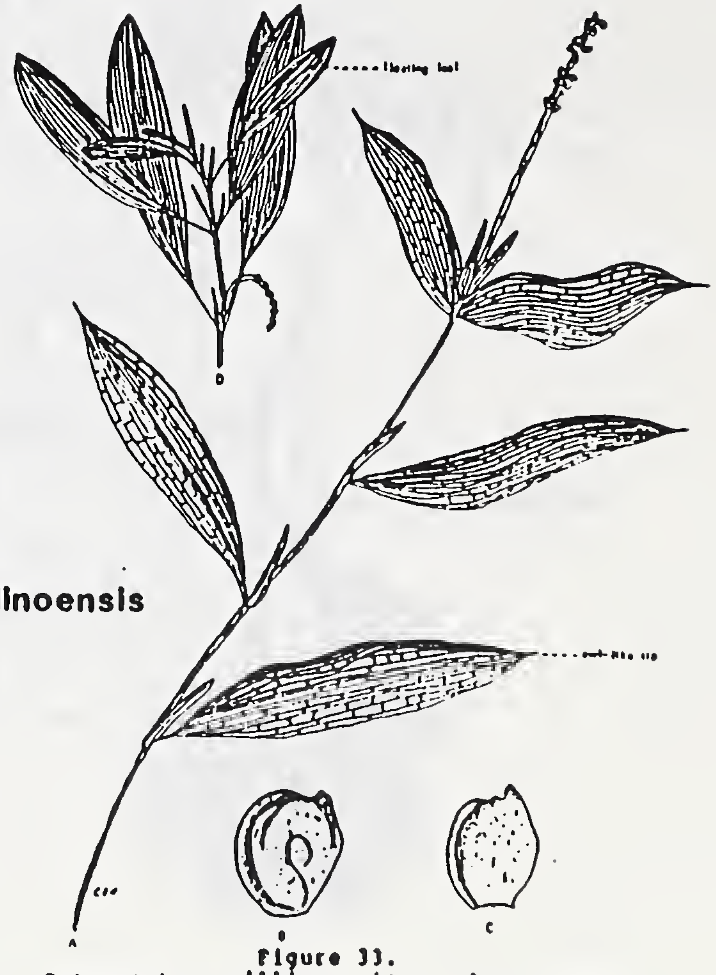


19. P. natans

P. natans: 1. Upper part of plant, × ¼. 4. Fruit, × 8.



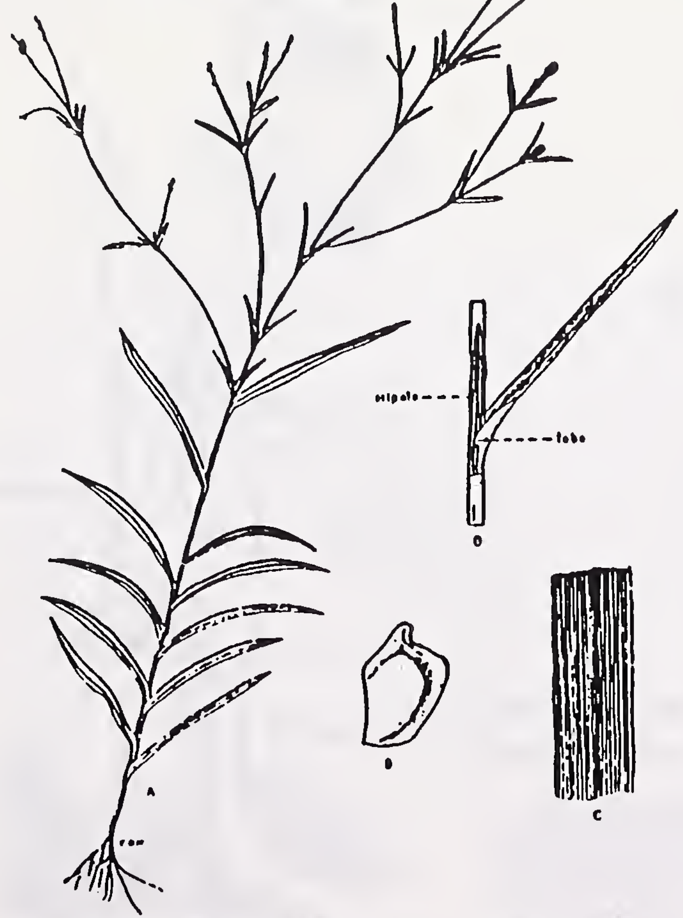
20. P. crispus



21. P. illinoensis

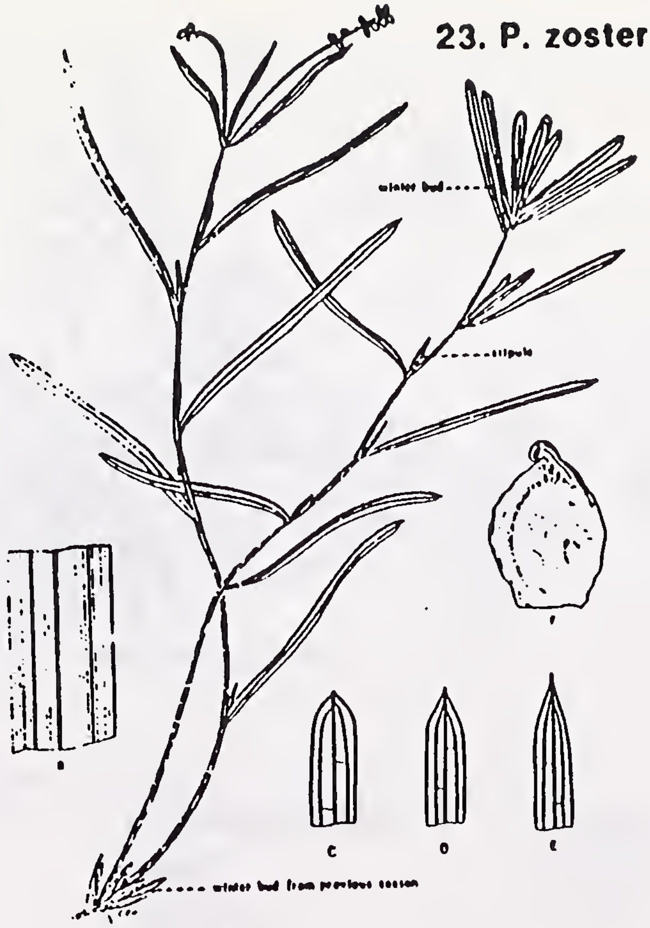
Figure 33.
Potamogeton illinoensis: A. upper portion of plant. B-C. fruits. D. upper portion of plant.

22. P. robbinsii



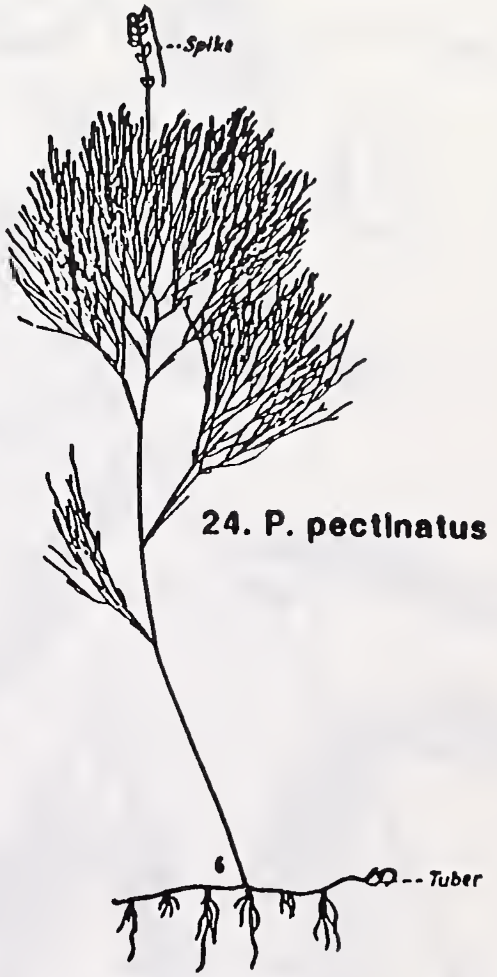
Potamogeton robbinsii: A. habit. B. immature fruit. C. portion of leaf D. leaf base.

23. P. zosteriformis


winter bud
stipule
B
F
C
D
E
winter bud from previous season

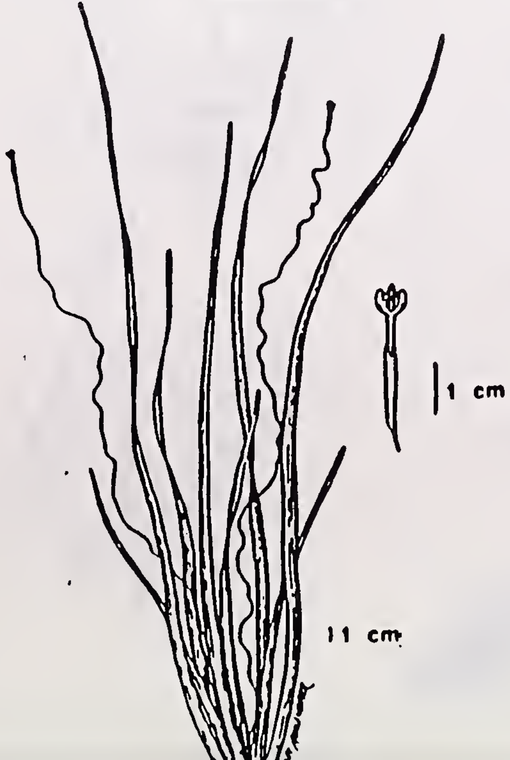
Potamogeton zosteriformis: A. habit. B. portion of leaf. C-E. leaf tips. F. fruit.

24. P. pectinatus

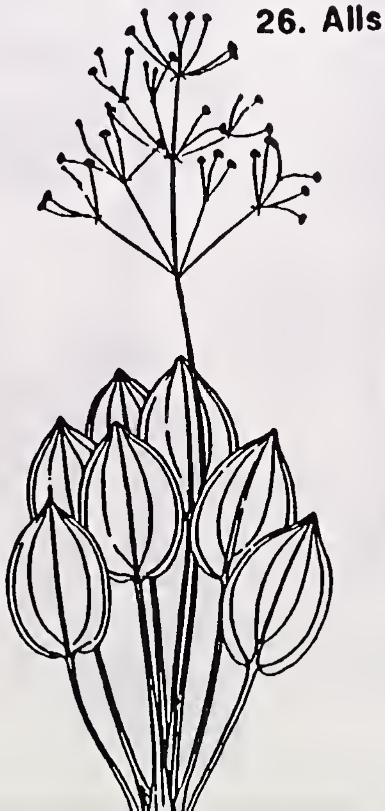


P. pectinatus: 6. Plant, × ¼.

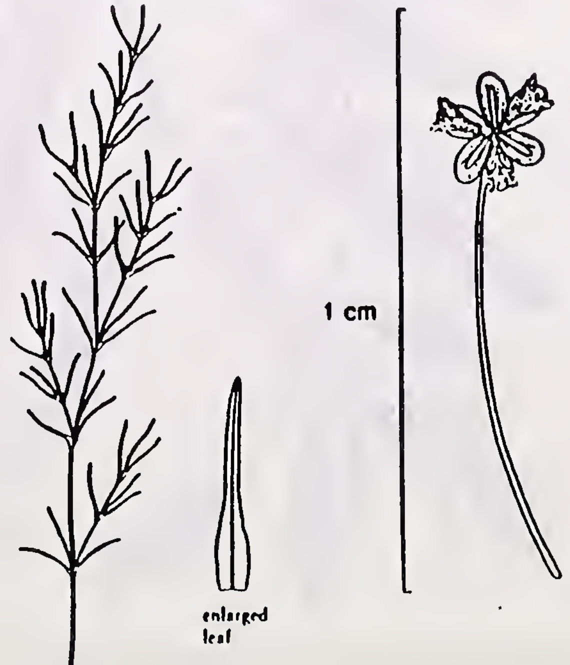
25. Vallisneria



26. Alisma



27. Najas



28. Elodea

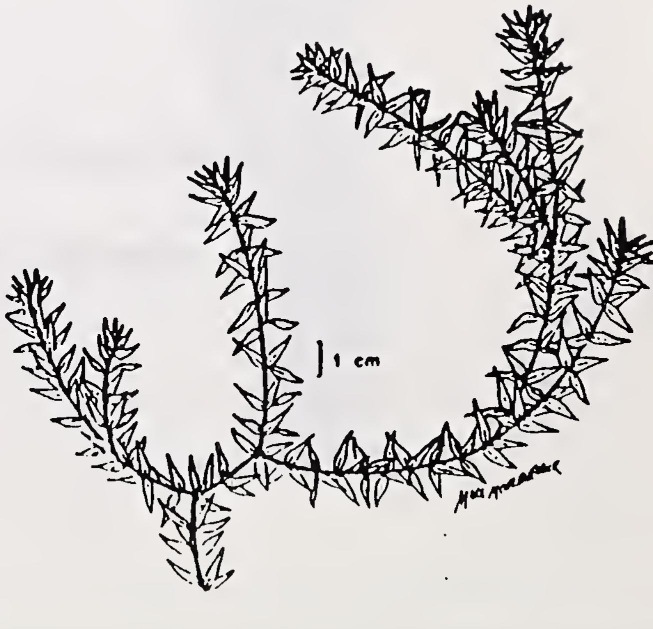


TABLE 4.1 IN-LAKE MANAGEMENT DECISION SELECTOR

This form is intended to aid in the evaluation of a particular management technique.

PREPARED BY LEE LYMAN

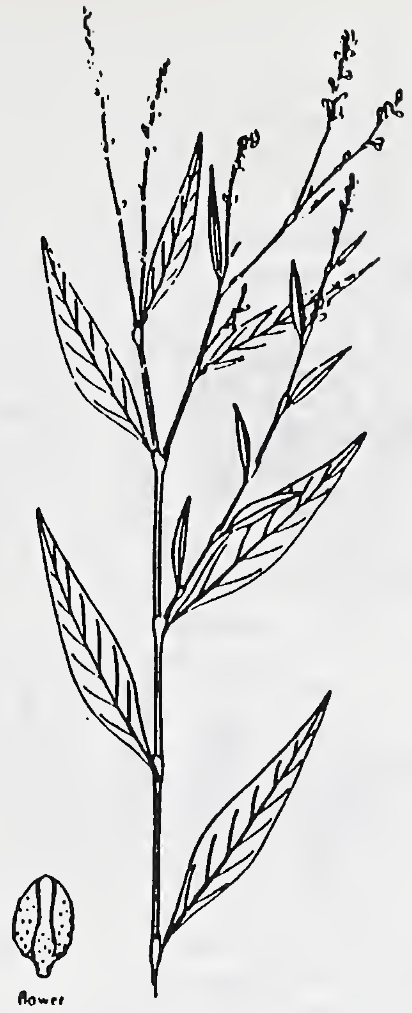
LYCOTT ENVIRONMENTAL RESEARCH, INC

CATAGORY	DREDGE		DRAWDOWN FLUSHING		AERATION		HERBICIDE		ALGAECIDE		HARVEST		HYDRO-RAKE		SEDIMENT TILLING		HYPO-LIM WITHDRAWEL		BENTHIC SCREEN		SEDIMENT OXIDATION		BIOLOGICAL		ALUM		DYE		DILUTION		ARTIFICIAL CIRCULATION		FOOD CHAIN MANIPULATION	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
OUTLET STRUCTURE ADEQUATE	5		10		1		3		3		1		1		1		8		1		1		9		3		10		5		5		1	
PRIVATE WELLS	10		10		1		6		4		2		2		2		1		1		1		1		1		7		1		1		1	
ASSOCIATED WETLANDS	9		8		1		2		1		1		3		1		1		1		1		2		1		1		1		3		1	
IMPACTS TO FISHERIES	10		8		7		3		2		8		10		10		8		8		8		10		3		2		8		10		10	
AMPHIBIANS	10		9		1		1		1		6		8		6		1		6		1		6		1		1		2		10		3	
MUSSELS	10		10		3		1		1		1		10		10		2		10		10		2		1		1		4		10		2	
CRAWFISH	10		8		1		1		1		1		10		10		1		10		8		7		1		1		4		10		3	
BENTHICS	10		10		1		2		4		3		10		10		2		10		10		8		1		1		7		10		3	
WATER FOWL	10		6		1		1		1		1		3		1		1		1		1		1		1		1		1		2		1	
PUBLIC DRINKING WATER SUPPLIES	10		8		1		10		10		5		5		5		1		1		5		3		1		1		1		1		1	
HYDROLOGY BUDGET	10		10		1		8		6		2		2		2		8		1		2		2		10		10		10		1		1	
EXPOSURE OF MOST AQUATIC PLANTS	8		10		1		8		1		8		8		8		1		8		1		8		1		1		1		2		1	
DISRUPTION OF RECREATIONAL ACTIVITIES	10		10		1		4		3		3		4		1		1		1		1		5		2		1		3		5		1	
IMPACTS TO NON-TARGET ORGANISMS	10		8		1		2		3		5		10		10		1		10		10		8		1		1		4		10		5	
SELECTIVITY FOR SPECIFIC AREAS OF POND	1		2		1		10		1		8		10		10		1		10		1		1		1		1		1		10		1	
SPECIES SPECIFIC	1		1		1		9		9		2		4		1		1		1		1		4		9		1		1		1		4	
LONGTERM EFFECTIVENESS	5		10		3		6		2		1		4		2		4		2		2		8		6		1		8		3		5	
TYPE OF POND BOTTOM	10		8		1		1		1		8		10		10		2		10		10		2		1		1		1		10		2	
DOWN STREAM EFFECTS	10		8		1		2		2		2		2		1		4		1		2		4		1		10		10		5		3	
AGRICULTURAL USE	10		8		1		10		8		1		2		2		8		1		2		3		1		3		5		1		2	
PERMITTING	10		5		2		8		7		3		3		4		2		1		3		10		2		6		5		3		4	
CONSERVATION COMMISSION	10		10		1		10		10		10		10		10		5		10		10		10		10		10		10		10		2	
DEP																																		
LAKES PERMIT/LICENSE	1		10		1		10		10		1		1		1		1		10		1		1		10		10		1		1		1	
DIV WATERWAYS	10		1		1		1		1		1		1		5		1		1		1		1		1		1		10		1		1	
WATER QUALITY CERTIFICATE	10		1		1		1		1		1		1		5		5		1		1		1		1		1		10		1		1	
WETLANDS	10		10		1		8		10		10		10		10		1		10		1		10		10		10		5		1		1	
PESTICIDE BOARD LICENSE	1		1		1		10		1		1		1		1		1		1		1		1		10		10		1		1		1	
ARMY CORPS OF ENGINEERS	10		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1	
FISHERIES & WILDLIFE	10		10		5		1		1		1		1		1		1		1		1		10		1		1		5		1		10	
MEPA	10		2		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1	
COST HIGH (H), MODERATE (M), LOW (L)																																		
INITIAL	H		M		H		M		L		M		H		H		H		H		H		M		M		H		H		H		M	
ANNUAL	L		L		M		M		L		M		M		M		L		H		H		M		M		H		M		H		L	
PER ACRE	H		L		H		L		L		M		M		M		M		H		H		M		L		H		M		H		L	

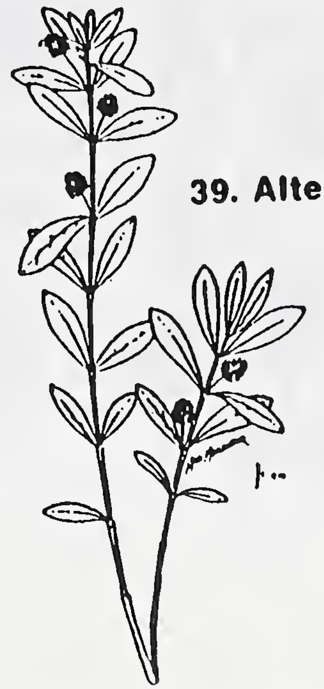
NOTE:• "1" IS NOT APPLICABLE OR SIGNIFICANT. "10" IS HIGHLY APPLICABLE OR SIGNIFICANT.

• THE COLUMN "G", IS A GENERAL EVALUATION DEVELOPED BY LEE LYMAN BASED ON 25 YEARS OF EXPERIENCE

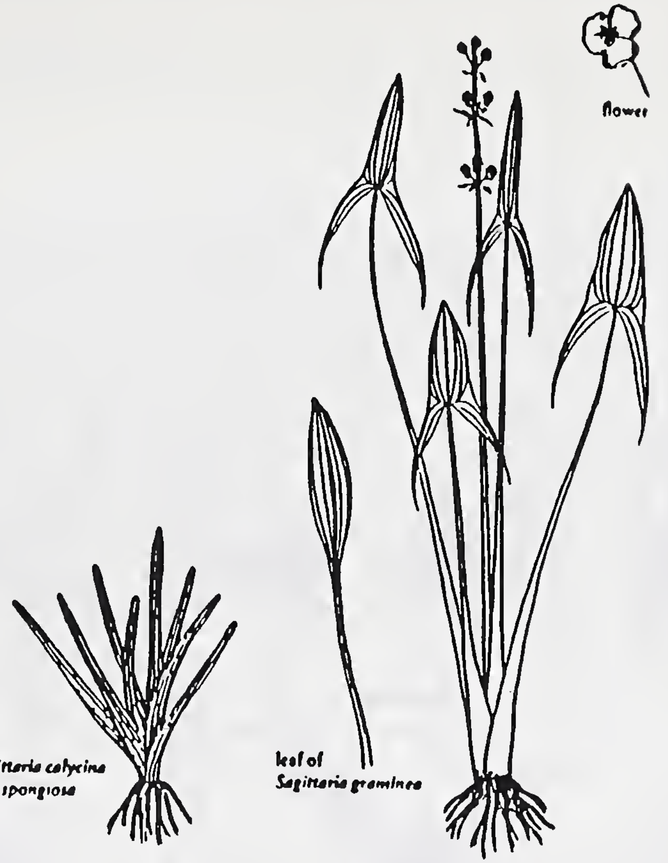
• THE COLUMN "S", IS INTENDED TO BE FILLED OUT BY THE USER FOR A SPECIFIC LAKE.



38. Polygonum

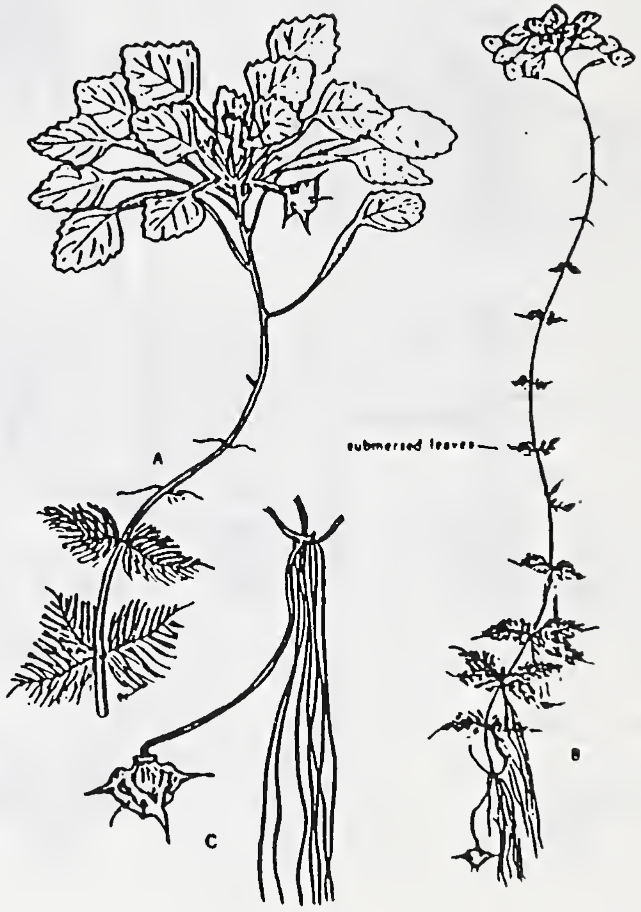


39. Alternanthera


flower
Sagittaria calycina ssp. spongiosa
leaf of Sagittaria graminea

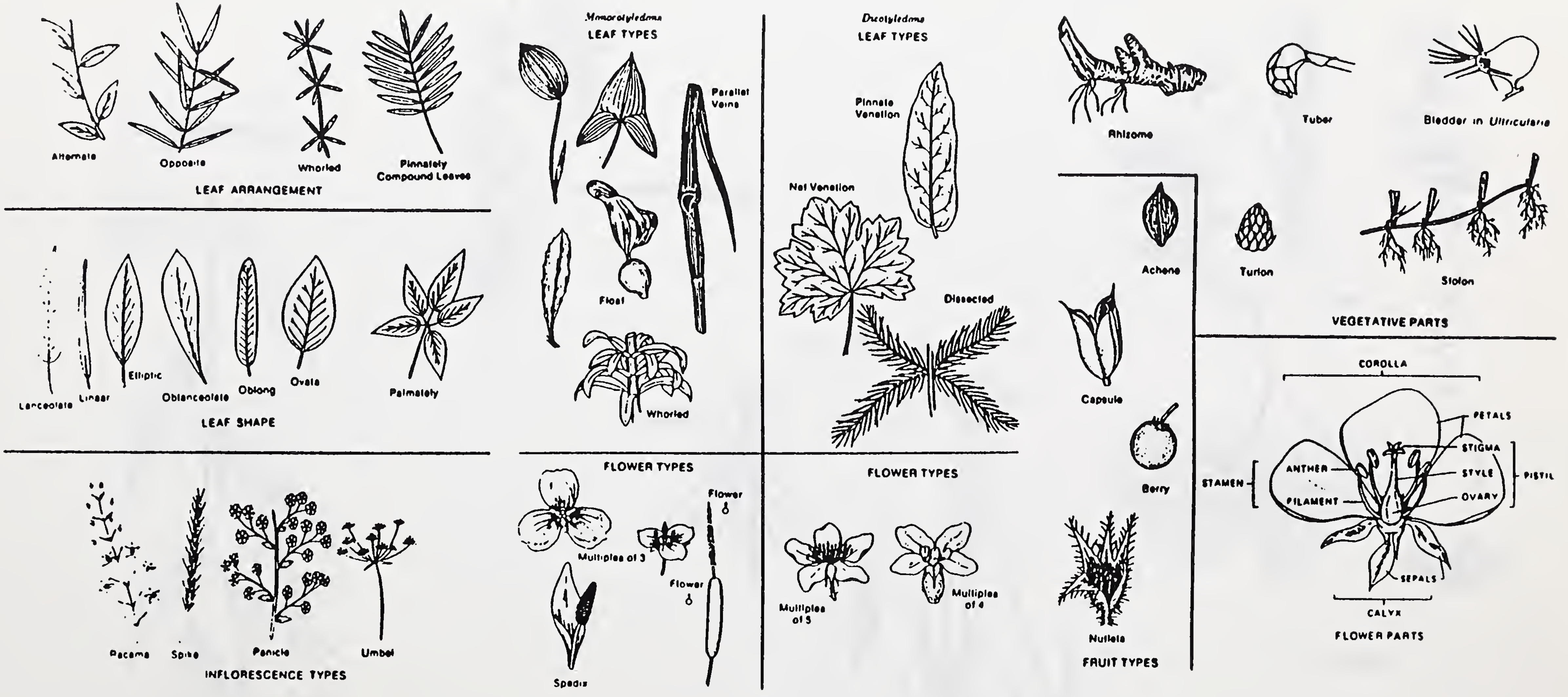
40. Sagittaria

41. Trapa



Trapa natans: A. habit of upper portion of plant with floating leaves, × ¼. B. habit, × ¼. C. basal portion with caltrop (nut) attached, × ¼.

ILLUSTRATED GLOSSARY



SOURCE: Westerdahl et al., 1988

KEY TO PLANT ILLUSTRATIONS

FIGURE #	COMMON NAME	SPECIES NAME	KEY
1	Duckweed	Lemna minor	W
2	Big Duckweed	Spirodela polyrhiza	W
3	Mud-midget	Wolffiella floridana	W
4	Watermeal	Wolffia columbiana	W
5	Watershield	Brasenia schreberi	H
6	American Lotus	Nelumbo lutea	H
7	Yellow Water Lily	Nuphar luteum	H
8	White Water Lily	Nymphaea odorata	T
9	Muskgrass	Chara vulgaris	F
10	Purple Bladderwort	Utricularia purpurea	W
11	Water Buttercup	Ranunculus trichophyllus	W
12	Nitella	Nitella flexilis	F
13	Eurasian watermilfoil	Myriophyllum spicatum	H
14	Fanwort	Cabomba caroliniana	H
15	Coontail	Ceratophyllum demersum	T
16	Water Star Grass	Zosterella dubia	T
17	Long-leafed Pondweed	Potamogeton amplifolius	F
18	Pondweed	Potamogeton nodusus	H
19	Floating-leafed Pondweed	Potamogeton natans	F
20	Curly-leafed Pondweed	Potamogeton crispus	W
21	Pondweed	Potamogeton illinoensis	H
22	Robbins Pond	Potamogeton robbinsii	H
23	Flat-stemmed Pondweed	Potamogeton zosteriformis	H
24	Sago Pondweed	Potamogeton pectinatus	F
25	Wild Celery	Vallisneria americana	W
26	Northern Water Plantain	Alisma plantago-aquatica	T
27	Bushy Pondweed	Najas guadalupensis	T
28	Waterweed	Elodea canadensis	W
29	Tussock sedge	Carex stricta	T
30	Common Spike-rush	Eleocharis palustris	T
31	River Bulrush	Scirpus fluviatilis	T
32	Rice Cutgrass	Leersia oryzoides	T
33	Common Reedgrass	Phragmites australis	T
34	Wild Rice	Zizania aquatica	T
35	Broad-leaved Cattail	Typha latifolia	H
36	Narrow-leaved Cattail	Typha angustifolia	T
37	Giant Bur-reed	Sparganium eurycarpum	T
38	Water Smartweed	Polygonum punctatum	T
39	Alligatorweed	Alternanthera philoxeroides	W
40	Duck Potato	Sagittaria latifolia	T
41	Waterchesnut	Trapa natans	H

GLOSSARY FOR PLANT IDENTIFICATION

achene - a type of one-seeded, dry, indehiscent fruit

adventitious - buds or roots that develop without pattern in an unusual or irregular position

alternate - said of a leaf borne singly at each node

annual - living only 1 year

axil - the angle between any two organs or structures

beaked - having a short, terminal projection

biennial - life cycle completed in 2 years or seasons

bladder - small structures on submersed leaves which act as traps for capturing insect larvae

bristle - a stiff hair or hairlike growth

calyx - the usually green, outer whorl of the perianth, composed of sepals

capsule - a dry, dehiscent fruit that splits three or more ways at maturity

catkin - the flowering head of a cattail (*Typha* spp.). Also used to describe the flowers of some other plant species

cordate - with a sinus (space between two lobes) and rounded lobes at the base, usually ovate in general outline, heart-shaped

corolla - the inner, usually colored whorl of the perianth, composed of petals

culm - the specialized stem of grasses, sedges, and rushes

cuticle - a waxy, protective layer on the surfaces of the leaves and stems of plants

dehiscent - splitting open at maturity

dicotyledon - plants with two seed leaves (usually broadleaf plants)

dioecious - having the staminate and pistillate flowers on separate plants

ellipsoid - referring to a solid object that is broadest at the middle, gradually tapering to both ends

elliptic - broadest at the middle, gradually tapering to both ends

emersed - rising above the water surface

entire - a margin without teeth, lobes, or division

fibrous - referring to roots borne in tufts

float - an inflated stem

frond - the body of a fern

herb - a nonwoody plant

indehiscent - not splitting open at maturity

inflorescence - a cluster of flowers

internode - stem region between nodes

lanceolate - lance-shaped; broadest near base, gradually tapering to the narrower tip

linear - elongated and uniform in width throughout

midrib - main rib of normal leaf running from base to apex

monocotyledon - plants with one seed leaf and parallel veined leaves (usually grasses, sedges, rushes)

monoecious - having staminate and pistillate flowers on the same plant

node - that place on the stem from which leaves, branchlets, and adventitious roots arise

oblanceolate - reverse lance-shaped; broadest at apex, gradually tapering to a narrow base

oblong - broadest at the middle, and tapering to both ends, but broader than elliptic

opposite - said of two leaves borne across from each other at the same node

ovate - broadly rounded at base, becoming narrowed above; broader than lanceolate

ovoid - referring to a solid object that is broadly rounded at the base, becoming narrowed above

palmate - divided radically, like the fingers of a hand

panicle - a type of inflorescence composed of several racemes

pendulous - hanging downward

perennial - living for more than 2 years

perianth - a collective term for the corolla and calyx

petal - one unit of the corolla

petiole - leaf stalk

pinnate - divided once into distinct segments

pistil - the ovule-producing (female) part of the flower

pistillate - bearing the female parts of the flower

prop root - a root produced near the base of the stem to give added support

raceme - a type of inflorescence where flowers with stalks are arranged along an elongated axis

rachis - a stalk bearing flowers or leaflets

rhizomatous - producing or possessing rhizomes

rhizome - an underground horizontal stem, bearing nodes, buds, and roots

rootlet - a small root

rootstock - subterranean stem

rosette - arrangement of leaves clustered symmetrically around the base of the stem

sepal - a single unit of the calyx

serrate -with sharp teeth pointing forward

sessile - without petioles, spikes, or stalks

sheath - tubular-type structure surrounding a plant part

spathe - a large sheathing leaflike structure surrounding or enclosing an inflorescence

spike - a type of inflorescence where flowers without stalks are arranged along an elongated axis

spikelet - a small spike

spine - a sharp-pointed outgrowth from a stem, leaf, or fruit

spinulose - bearing small spines

spur - a saclike extension of the flower

stamen - the pollen-producing (male) part of the flower

staminate - bearing the stamens, male parts of the flower (see pistillate)

stolon - a slender, horizontal stem, above or below the ground

striations - small lines or grooves

submersed - living below the surface of the water

teeth - any marginal protuberance, usually sharp-pointed

tuber - a short, thickened fleshy part of an underground stem. New plants develop from buds that grow in the axils of the minute scale leaves of a tuber

tuft - cluster of leaves or other elongate structures

turion - a winter bud that forms in the leaf axils of certain aquatic plants. When a plant matures, turions may drop onto bottom mud and produce new plants. Hydrilla plants produce turions

umbel - a type of inflorescence in which the flower stalks arise from the same level

unisexual - bearing either one sex or the other, but not both

vein - an elongated conducting structure visible on leaves

whorl - an arrangement of three or more structures at a node

SOURCE: Westerdahl et al., 1988

CODE TO PLANT TAXONOMIC IDENTIFICATION KEYS

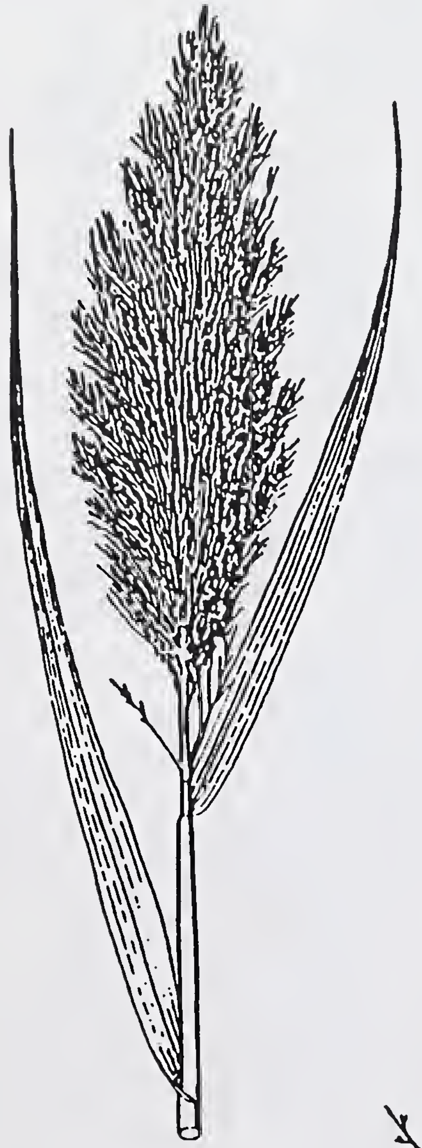
F = Fassett, N.C. 1957, A Manual of Aquatic Plants. University of Wisconsin Press, Madison, WI.

H = Hellquist C.B. and G.E. Crow. 1980-1985 (Series). Aquatic Vascular Plants of New England: Parts 1-8. New Hampshire Agricultural Experiment Station Bulletin Numbers 515, 517, 518, 520, 523, 524, 527, 528. Durham, NH.

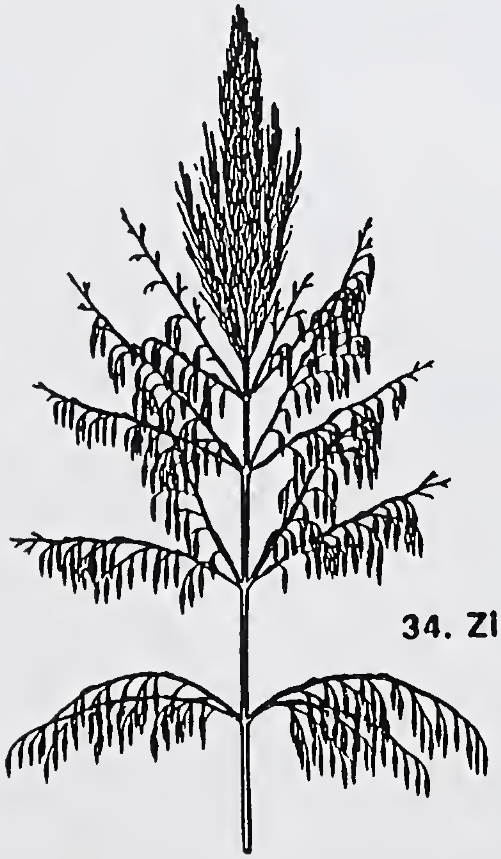
Mackenthum, K.M., Ingram, W.M. and R. Porges. 1964. Limnological Aspects of Recreational Lakes. United States Public Health Service. Division of Water Supply and Pollution Control, Cincinnati, OH.

T = Tiner, R.W. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. University of Massachusetts Press. Amherst, MA.

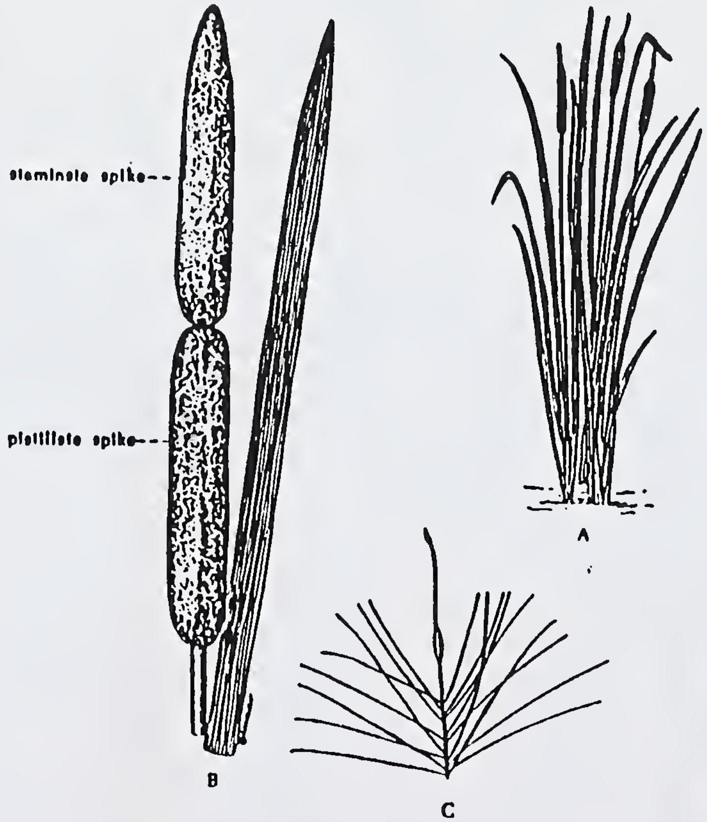
W = Westerdahl, H.E. and K.D. Getsinger (editors). 1988. Aquatic Plant Identification and Herbicide Use Guide. Tech. Rept. A-88-9, Aquatic Plant Control Research Program, USACOE, Waterways Experiment Station, Vicksburg, MI.



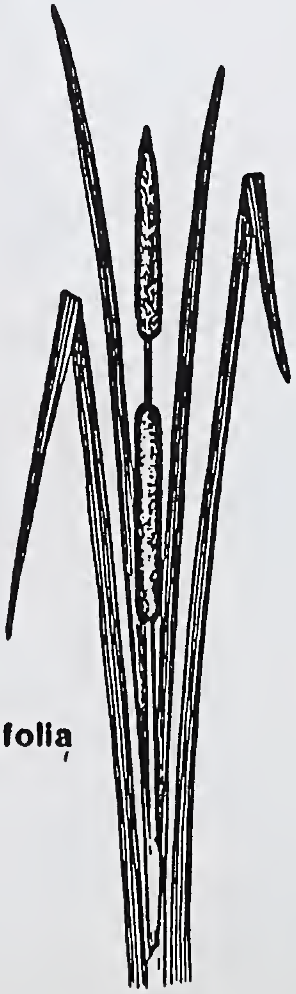
33. Phragmites



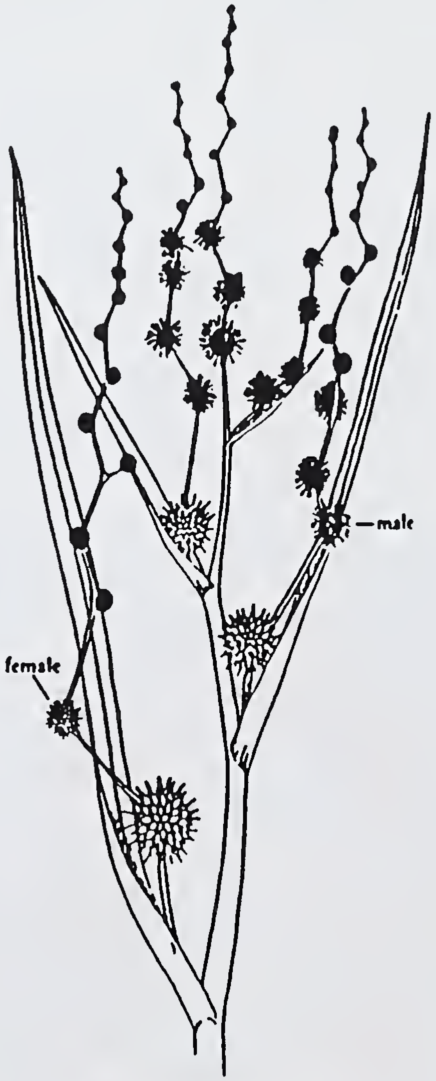
34. Zizania



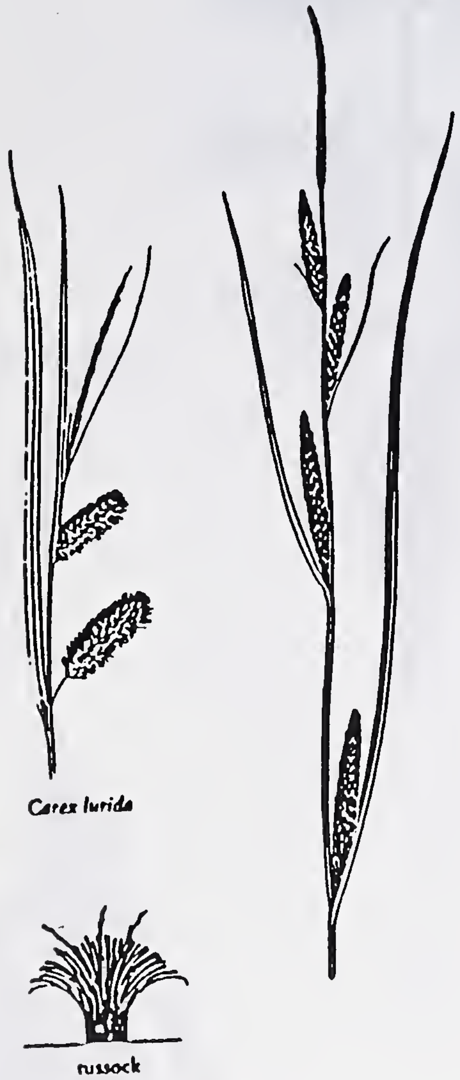
35. Typha latifolia



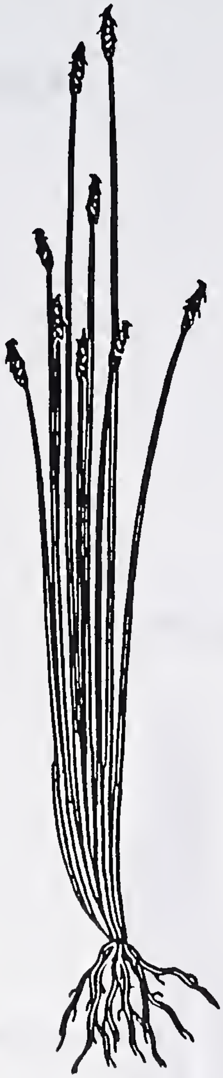
36. T. angustifolia



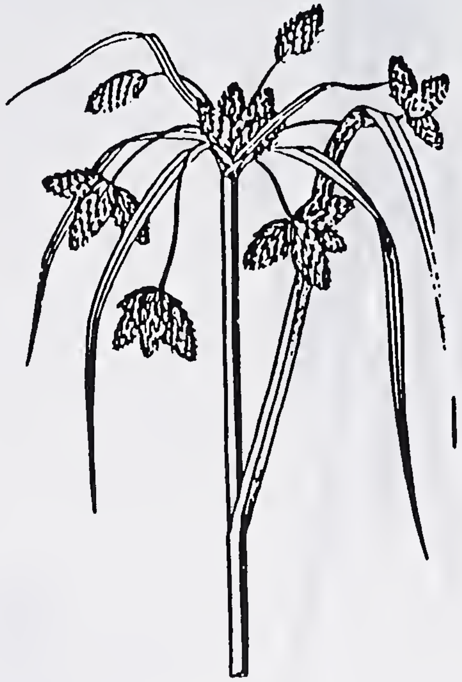
37. Sparganium



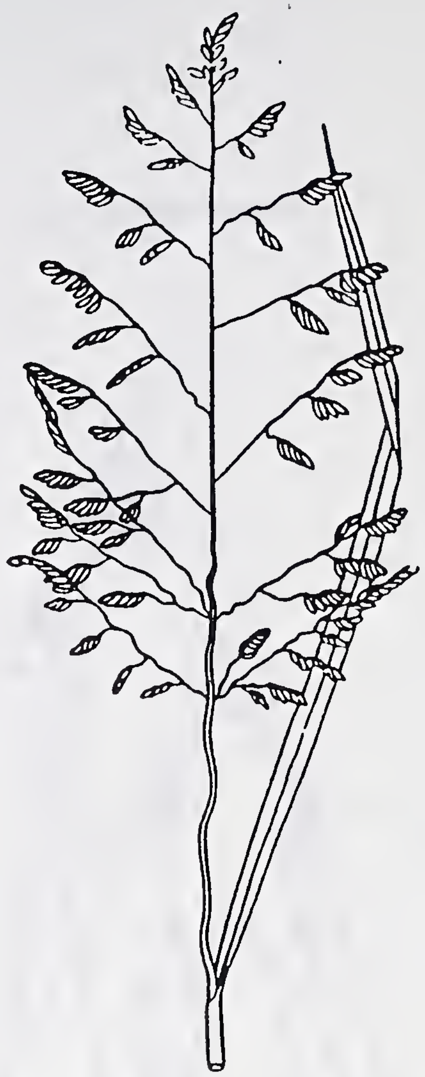
29. Carex



30. Eleocharis



31. Scirpus



32. Leersia

LAKE ASSESSMENT WORKSHEETS

WORKSHEET: LAKE SHAPE AND SIZE

Lake /Pond Name:
Region:
Investigator:
Date:

Sketch or insert map of lake shape and size:

WORKSHEET: LAKE BATHYMETRY

Lake /Pond Name:
Region:
Investigator:
Date:

Describe technique used to determine lake/pond bathymetry (depth):

Sketch or insert map of lake/pond bathymetry:

WORKSHEET: SAMPLING LOCATIONS

Lake /Pond Name:
Region:
Investigator:
Date:
Time:

Describe sampling locations/stations:

Prepare sketch of sampling locations/stations:

LAKE/POND SAMPLING DATA SHEET

LAKE/POND NAME ______________________ DATE __________

RIVER BASIN ______________________ PERSONNEL __________

WEATHER CONDITIONS: ______________________

______________________ SDT= __________

Observation Number	Lake Station	Depth (m)	Temp. (degrees C)	Dissolved Oxygen(mg/l)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

	STATIONS				
PARAMETERS (units)	1	2	3	4	5
pH (SU)					
Total Alk. (mg/l)					
Spec. Cond. (umhos/cm)					
Tot. Susp. Sol. (mg/l)					
Turbidity (NTU)					
Chloride (mg/l)					
Iron (mg/l)					
Ammonia-N (mg/l)					
Nitrate-N (mg/l)					
Kjeldahl-N (mg/l)					
Soluble Phos. (ug/l)					
Total Phos. (ug/l)					
Fecal Coliform/100 ml					
Total Coliform/100 ml					

TEMPERATURE AND OXYGEN DEPTH PROFILES

DIAGRAMMATICAL SKETCH OF LAKE OR POND WITH APPROXIMATE LOCATIONS OF SAMPLING SITES

ADDITIONAL NOTES:

WATER QUALITY PARAMETER GRAPH

Lake/Pond Name:
Region:
Investigator:
Parameter:

PARAMETER________________________

U
N
I
T

DATA SHEET: WATER QUALITY MEASUREMENTS

PARAMETER	DATE OF SAMPLES-->									

WORKSHEET: VEGETATION

Lake /Pond Name:
Region:
Investigator:
Date:

Describe the types and locations of macrophytes and algae in the lake/pond:

Prepare sketch of macrophyte species and algal blooms in lake/pond:

SECTION 2.

WATERSHED ASSESSMENT

WATERSHED ASSESSMENT

WATER AND THE HYDROLOGIC CYCLE

See page 2-8 through 2-11 of coursebook.

a. **Hydrologic cycle**

1. Inflows:
   - precipitation: snow, rain, hail,tributary flow: feeder stream flow,
   - overland flow: rain-induced surface flow (runoff),
   - ground water flow: from upgradient recharge areas.

2. Outflows:
   - evaporation from open water surfaces. Ground water outflow: infiltration into downgradient soils or bedrock,
   - stream flow from draining streams,
   - transpiration: uptake and respiration by plants.

b. **Watersheds and Drainage Basins**
Watershed is the land area from which water drains to a lake (or stream). It consists of two components:

1. Surface Drainage Basin is the land area from which all surface water drains to a lake or stream at a lower elevation.

2. Ground Water Drainage Basin is the land area and associated subsurface through which ground water drains to a lake or stream at a lower elevation.

c. **Hydrologic Budget** quantifies the inputs and outputs of the hydrologic cycle for lake system over a suitable time period. A hydrologic budget is necessary before evaluating nutrient pollutant loadings to a lake system.

SURFACE DRAINAGE BASIN

a. Characteristics

See page 2-11 through 2-14 of the coursebook.

1. Area: Size in square miles, kilometers or similar units categorized as open water or land.
2. Soil types and erodibility: critical for determining appropriate land uses and erosion control.
3. Types and extent of vegetative cover: input to estimating runoff and evapo-transpiration.
4. Types and extent of developed areas: categorization as agricultural, industrial, conservation, and residential uses critical to assessing potential water quality impact problems.
5. Average and maximum slope: input to estimating time of concentration and erosion potential.
6. Time of concentration: the time for a rain or water drop to travel from the furthest end of the watershed to the lake.

b. Delineation of surface drainage basins

Draw watershed divide boundaries on appropriate scale topographic map using two simple rules:

1. Draw divide boundaries perpendicular to contour lines.
2. Draw divide boundaries through the center of contour saddles and closed contour loops.

GROUND WATER DRAINAGE BASINS

a. Ground Water

See page 2-14 through 2-26 of the coursebook.

Water which saturates pore spaces between gravel, silt, sand, or clay particles or in bedrock fractures in the subsurface environment.

1. Key terms and Considerations

- unsaturated (aerated) zone
- saturated zone

- Water table = upper elevation of saturated zone. Derived primarily from precipitation which has infiltrated into the subsurface environment.
- Ground water quality may be influenced by the types of geologic deposits.
- Porosity describes the void volume of a geologic material, i.e., the amount of air or water-filled voids within a unit volume of material.
- Permeability is a measure of a geologic material's ability to transmit water.
- High porosity materials, like clays, may be very impermeable because the voids are not interconnected.
- Aquifers hold and transmit sufficient quantities of ground water to permit economic development.
- Confined aquifers have impermeable confining layers above and below the aquifer materials; the water table elevation may rise above ground level if the upper confining layer is penetrated by a well.
- Perched water table: a layer of saturated soil formed on a low permeability layer located above the main water table.
- Ground water moves from higher water table elevations to lower water table elevations;
- Flow is a function of elevation and pressure differences and properties of the soil or bedrock matrix (hydraulic conductivity);
- Ground water flow is three dimensional: downwelling usually occurs at the higher elevations of a recharge area while upwelling usually occurs at the lower elevations of a recharge area.
- Ground water velocities are slower than surface water velocities, typically varying between several feet per day to several feet per year.
- Baseflow: ground water discharge into lakes and streams.
- Interflow: horizontal ground water movement through the unsaturated zone.

b. Ground Water Drainage Basins

1. Characteristics
   - Soils: Types and extent (SCS soil maps);

   - Geology: unconsolidated sediment versus bedrock types; fractures and faults; history of glacial, wind or stream action; depth to bedrock;
   - Hydraulic conductivity: location and extent of high, low and non-permeable geologic formations;
   - Presence of "losing" or "gaining" surface water bodies;
   - Aquifers: volume and areal extent of each type: confined, unconfined and perched;
   - Time of travel.

2. Tools and Methodologies
   - Unconsolidated Sediments versus Bedrock
   - Hydrogeologic Investigations: USGS atlases & geologic quadrangle maps
   - Drilling
   - Wells and Piezometers
   - Water Table Elevation Maps
   - Geophysical Investigations
   - Delineation

WATERSHED -LAKE INTER-RELATIONSHIPS

WATERSHED DELINEATION

Objective:

To delineate a lake or pond watershed, which is comprised of surface water and ground water drainage basins.

Procedure:

1. Review USGS topographic quadrant base map (or other map showing sufficient topographic detail) of the study area.

2. Identify the highest elevation points surrounding the lake which appear to contribute surface runoff to the lake. Think about whether water, if released in sufficient quantity, would flow to the lake from those high points.

3. Using a pencil and beginning with the lake outlet(s), delineate the surface water drainage basin boundaries using the following two rules :

   a. Draw divide boundaries perpendicular to contour lines.

   b. Draw divide boundaries through the center of contour saddles and closed contour loops.

> REMEMBER:
> Water flows perpendicular to the contour lines.
>
> Water flows down the V-shaped valley contours from the narrowest part of the V to the widest part.

4. If the drainage basin is very large or if it contains a number of different lakes, sub-divide it into sub-drainage basins by delineating divide boundaries for each major tributary and/or lake. Each sub-drainage basin must possess all the characteristics of a normal watershed; each has a collecting surface water body

(stream, pond, lake) which then drains directly or indirectly into the lake of concern.

5. Before drawing in the divide boundaries using a pen, review your delineation by mentally following imaginary surface flow from the boundary down to the receiving body. Examine the boundary perimeter and ensure that all rainfall falling outside the boundary will not move towards and eventually reach the study area.

6. Using a planimeter or some other method, estimate the area of the surface water drainage basin and its component sub-drainage basins in acres or square miles or square kilometers.

7. Determine the different land uses (agricultural, residential, industrial, commercial, conservation, etc.) present within the drainage basin using zoning or land use planning maps, if available. If possible, estimate the acreages (or square miles/kilometers) of each land use type. This information will be useful in assessing sources of water quality degradation (i.e. agricultural practices contribute fertilizers and pesticides, urban development contributes road runoff and lawn care products).

8. While the ground water drainage basin for a lake often coincides with its surface water drainage basin, it may not have the same boundaries. Parts may extend beyond the surface water drainage basin or, because of bedrock outcrops (ledge), the ground water drainage basin may coincide with only part of the surface water drainage basin. Proper delineation of the ground water drainage basin requires an examination of the surficial and bedrock geology by an experienced professional. However, assuming that the surface water drainage basin encompasses the ground water drainage basin may suffice for a "first-cut" approximation.

HYDROLOGIC BUDGET ESTIMATION

Objective:

To estimate the magnitude of the lake system's (that is, the lake and its watershed) annual hydrologic inputs and outputs.

Procedure:

1. Identify all hydrologic inputs: precipitation, tributary inflow, overland flow, ground water inflow.

2. Collect information from federal, state and local offices to attempt estimation of the annual inflow (typically in million gallons per year) for each input. The National Oceanic and Atmospheric Administration (NOAA), the National Weather Bureau, and local officials may have long term precipitation records. Stream flows may have been gauged by the US Geological Survey, the Army Corps of Engineers, state offices, or local universities. Overland flow and ground water inflow depend on more site-specific factors such as soil types, vegetative cover, surficial geology, etc. and may require evaluation by an experienced professional.

3. Identify all hydrologic outputs: stream flow, ground water infiltration to soils and bedrock, evapo-transpiration, and industrial, commercial, agricultural, and public/private water supply withdrawals. USGS hydrologic atlases may provide estimates of annual evapo-transpiration and potential evapo-transpiration for the area of concern. State and local agencies may provide estimates of human ground and surface water withdrawals through well log permits and withdrawal permits. Stream flow data may be available from the sources mentioned above. Estimation of ground water infiltration to soils and bedrock and evapo-transpiration may require evaluation by an experienced professional.

4. Total up inputs and outputs. A usable hydrologic budget requires that the inputs and outputs balance out.

MONITORING WELL INSTALLATION AND SAMPLING

Objective:

To install monitoring wells as a means of obtaining ground water elevation, flow and water quality information.

Procedure:

1. Conduct a desk study of available hydrogeologic information of the study area and its locale by reviewing USGS, Soil Conservation Service (SCS), state, and consultants' reports. Other sources of data include water supply and monitoring well boring logs and deep test pit logs.

2. Obtain a good topographic map of the study area and delineate its surface water drainage basin.

3. Determine the investigation's objective(s): water table elevations, direction of ground water flow, existing ground water quality, installation of a monitoring program, etc. Well siting and soil sampling protocol will depend upon the investigation's objective(s), the level of detail needed to resolve the issue of concern and resource/time constraints. Sampling protocol depends on the types of samples desired (soil, water, disturbed, undisturbed), the sampling frequency necessary and the need to prevent cross-contamination. Typically, selecting well sites and devising a soil sampling protocol will require input from an experienced professional.

4. Select the most appropriate boring method: hand auger, hollow stem, solid stem, etc. This choice will depend on budget, sampling protocol, type of well to be installed, subsurface materials (bedrock, till, glacial outwash, etc.), maximum drilling depth, and other factors.

5. Conduct the drilling program. Each boring must be "logged" (recorded) by an experienced geologist or hydrogeologist. Many drilling companies will provide you with boring logs made by their drillers. However, most drillers do not have geological training and these logs may not be adequately rigorous for the investigation. The logs should describe the characteristics of each sample collected: colors; type, coarseness and quantity of each geologic material (sand, silt, gravel, etc.); layering, odor, presence of contaminants, etc. The logger must also record the presence and location of perched water tables, confining

layers, ground water table, refusal, and any other information which may aid in establishing the hydrogeologic situation.

6. Well installation should follow completion of each boring. As above, experienced technical input is usually required in selecting the type and diameter of well material (PVC, stainless steel, Teflon, etc.), well screen slot size, well screen length and placement, type and location of sealing materials, and the method of well development. For the "simplest" case in which the investigation should determine ground water elevation, horizontal flow direction and where there is no threat of contaminant presence[1], two inch diameter PVC risers with 0.010 slot size well screens and conical well points are often selected because of economy and ease of installation.

Determination of Ground Water Table Elevations and Flow Direction

1. The wells must be surveyed to determine the elevation of the well top with regard to some reference datum, usually mean sea level.

2. After allowing at least 24 hours for the ground water level to equilibrate, ground water elevation measurements can be taken using a variety of methods. The most commonly used methods include "plunking" and chalk-the-tape. One can estimate ground water elevation within the well through attaching a fitting (which makes a loud sound or "plunk" when first coming into contact with the water surface) to an accurate measuring tape. A more accurate method is to chalk a fiberglass or steel surveyors tape and lower it into the well. The ground water elevation within the well is calculated by subtracting the length of wetted chalk from the top of the well measure.

3. A ground water elevation map can be produced from a set of same-day measurements for a site plotted on an accurate topographic plan showing well locations. However, care must be taken in interpreting the water table elevation measurements and constructing the elevation contours. It is very important that an experienced professional carry out and/or review the work.

4. Ground water flow direction can be read from the ground water elevation map in the same manner as one determines surface runoff

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[1] Some volatile organic compounds present in the ground water or soil water as contaminants can react with the PVC to weaken the well material and produce other organic compounds.

from the elevation contours shown on a topographic map. Water flows perpendicular to the contour lines.

Water Quality Analyses

1. Water quality analyses are typically done to determine the presence and quantity of the following compounds: iron, manganese, sodium or chloride (salt), total and ortho-phosphate, Kjeldahl, nitrite, nitrate, and ammonia nitrogen, volatile organic compounds (VOCs), metals (lead, cadmium, arsenic, copper, etc.) pesticides and herbicides, pH, alkalinity, hardness, fecal and total coliforms, and specific conductivity. The methodology usually includes the following steps:

    a. Purge the well of five to ten well volumes to establish a good connection between the aquifer and the well. A bailer, pump or, less accurately, air injection may be used.

    b. Collect samples using a clean sampling bailer and carefully fill the sample bottles.

    c. Transport the sample bottles to an analytical laboratory as quickly as possible.

BUILD-OUT ANALYSIS

Objective:

To determine the existing and saturation levels of development allowed in an area as programmed by zoning or land use regulations.

Procedure:

1. Collect zoning (or land use planning) maps for the study area and list all relevant zoning classifications.

2. Determine the minimum lot size and frontage for each zoning classification using the relevant rules and regulations for minimum lot sizes, frontage requirements, etc..

3. Measure the total area in acres (sq. miles/kilometers) for each zoning classification within the study area.

4. Using assessor's maps (or some other source), determine the total number of existing developed and undeveloped lots. Sum up the developed lot acreage for each zoning classification

5. A parcel-by-parcel review is necessary to obtain an accurate estimation of buildout potential. For each parcel, determine the number of lots which may be created through land subdivision based upon zoning requirements and environmental constraints. Where time constraints preclude the possibility of conducting a parcel-by-parcel buildout analysis, a rough buildout estimation is achieved through subtracting the total developed lot acreage from the total acreage for each zoning classification. The acreage of undeveloped land within each zoning district is then divided by the minimum lot size to yield a rough estimate of the maximum possible number of additional lots which could be developed.

6. Construct a table which summarizes, for each zoning classification, the number (and total acreage) of existing developed lots and the maximum number of additional lots possible given zoning. Total the number and acreages of developed and developable lots. Calculate the relative percentage of developed lots and developed acreage for each zoning classification.

7. In cases where the buildout analysis will be used to estimate nutrient loading to ground waters, one should also differentiate between the number of existing and future lots which would be publicly sewered, rather than served by on-site septic systems.

NUTRIENT LOADING ANALYSIS

Objective:

To estimate existing and future nutrient loadings associated with current and saturation levels of development. This section focuses on estimation of phosphorus loading because this nutrient is most directly related to lake and pond productivity.

Procedure:

1. Carefully select appropriate unit loading rates for all relevant land uses within the study area. Land uses which should be considered include crop and livestock agriculture; lawns and turfgrass; unsewered residences, businesses, institutions, and factories; roads, driveways and parking lots; building roof areas; among others. This information may be obtained through literature review and through local conservation/environmental agencies such as the Soil Conservation Service and U.S. Department of Agriculture.

2. Determine an appropriate unit loading rate for atmospheric deposition. Determine the type, extent and efficiency of storm water management systems within the study area. If most of the study area is serviced by an operating storm water management system, the runoff-borne phosphorus is usually not included the lake loading calculations unless the infiltration structures lie within 100 meters upgradient of the lake or its tributaries.

3. Determine the number of existing and potential unsewered residences, businesses, institutions, and factories within a 100 meter zone around the lake from the build-out analysis results.

4. Determine acreages of each land use type identified above (step # 1) within the study area.

5. Estimate the phosphorus contribution for each land use type by multiplying acreages by the unit phosphorus loading rates.

6. Sum up all phosphorus contributions to determine the total annual phosphorus loading to the system under the existing and saturation development scenarios.

7. Take the hydrologic budget estimate of total inflow to the lake and divide it into the total annual phosphorus loading to give an average annual phosphorus concentration flowing to the lake for saturation and development conditions.

8. The analysis results for the existing development scenario should be compared with observed ground and lake water measurements to determine whether the model requires calibration. Potential adjustments include seasonality factors, accounting for in-lake sediment re-suspension, low (or high) precipitation years, etc.

WATERSHED ASSESSMENT WORKSHEETS

WORKSHEET: WATERSHED DELINEATION

Lake /Pond Name:
Region:
Investigator:
Date:

Insert U.S. Geological Survey topographic map of lake/pond and its delineated watershed:

WORKSHEET: MONITORING WELL LOCATIONS

Lake /Pond Name:
Region:
Investigator:
Date:

Describe well installation:

Prepare sketch of well locations:

WORKSHEET: BUILDOUT ANALYSIS

Lake /Pond Name:
Region:
Investigator:
Date:

Describe methodology and assumptions used to conduct a buildout analysis for the watershed of the lake/pond:

WORKSHEET: BUILDOUT COMPUTATIONS

Lake /Pond Name:
Region:
Investigator:
Date:

WORKSHEET: NUTRIENT LOADING

Lake /Pond Name:
Region:
Investigator:
Date:

Describe methodology and assumptions used to estimate nutrient loading for the watershed of the lake/pond:

WORKSHEET: NUTRIENT LOADING COMPUTATIONS

Lake /Pond Name:
Region:
Investigator:
Date:

SECTION 3.

CAUSES OF LAKE PROBLEMS AND THEIR IDENTIFICATION

CAUSES OF LAKE PROBLEMS AND THEIR IDENTIFICATION

COMMON AQUATIC PROBLEMS

a. Weed Infestation

See page 3-11 through 3-12 of coursebook.

1. Causes
    - overfertilization
    - suitable sediment
    - sufficient light
    - absence of toxic materials
    - insufficient grazing
    - appropriate water level
    - lack of physical disturbance

2. Ecological implications
    - exotic invasion
    - habitat alteration
    - fluctuating oxygen
    - algal inhibition
    - food resource

3. Use impairment
    - potable supply
    - contact recreation
    - fishing
    - boating
    - aesthetics

b. Algal Bloom

See page 3-13 of coursebook.

1. Causes
    - overfertilization
    - sufficient light
    - lack of toxic substances
    - insufficient grazing

2. Ecological implications
    - food resource
    - fluctuating oxygen
    - taste and odor
    - toxicity to animals/humans
    - inhibition of rooted plants

3. Use impairment
    - potable supply
    - contact recreation
    - fishing
    - aesthetics

c. **Fish Stunting**

See page 3-13 of coursebook.

1. Causes
    - insufficient predation
    - excessive refuges
    - food shortages
    - fishing practices

2. Ecological implications
    - increased food for predators
    - decreased zooplankton
    - increased algae

3. Use impairment
    - fishing
    - aesthetics
    - contact recreation

d. **Fish Kill**

1. Causes
    - natural mortality
    - fishing pressure
    - temperature change
    - insufficient oxygen
    - toxic substances

2. Ecological implications
    - loss of trophic level
    - nutrient recycling
    - food resource loss

3. Use impairment
    - fishing
    - potable supply

See page 3-15 of coursebook.

e. Swimmers Itch

1. Causes
    - suitable habitat with hosts for schistosomes

2. Ecological implications
    - parasitism

3. Use impairment
    - contact recreation

See page 3-15 of coursebook.

f. Leeches

1. Causes
    - suitable habitat with hosts for leeches

2. Ecological implications
    - parasitism

See page 3-16 of coursebook.

3. Use impairment
    - contact recreation

g. Aggressive Waterfowl

1. Causes
    - desirable habitat
    - overabundant birds

2. Ecological implications
    - fertilization
    - predation/grazing
    - fecal bacteria loading

3. Use impairment
    - contact recreation
    - potable supply

See page 3-16 of coursebook.

h. Shallowness

1. Causes
    - natural morphometry
    - erosion/sedimentation
    - accumulated organic matter

2. Ecological implications
    - plant growth
    - habitat change
    - sediment resuspension

3. Use impairment
    - contact recreation
    - boating
    - fishing
    - flood control
    - water supply

See page 3-16 of coursebook.

i. Inhospitable Lake Bottom

1. Causes
    - type of sediment
    - obstructions

2. Ecological implications
    - habitat structure
    - oxygen demand
    - taste and odor

3. Use impairment
    - contact recreation
    - boating
    - potable supply

See page 3-16 of coursebook.

j. Taste and Odor

1. Causes
    - algal blooms
    - weed infestations
    - low oxygen chemistry
    - fish kill
    - watershed inputs

2. Ecological implications
    - sensory impacts on fauna

3. Use impairment
    - potable supply
    - contact recreation
    - aesthetics
    - boating
    - fishing
    - hunting

See page 3-17 of coursebook.

k. Color and Turbidity

1. Causes
    - watershed inputs
    - sediment-water interaction
    - algae

2. Ecological implications
    - predation
    - plant growth
    - fertilization

3. Use impairment
    - potable supply
    - contact recreation
    - aesthetics
    - fishing

See page 3-17 through 3-19 of coursebook.

l. User Conflicts

1. Causes
   - incompatible uses
   - insufficient space
   - inadequate user management

2. Ecological implications
   - direct interference
   - habitat destruction

3. Use Impairment
   - Any or all, depending on conflict

CAUSES OF LAKE CHANGE

See page 3-20 of coursebook.

a. Watershed Alteration

1. Natural changes
   - sediment build-up
   - fertilization
   - species replacement
   - catastrophic events

2. Urbanization impacts
   - runoff
   - erosion
   - waste disposal

3. Agricultural impacts
   - runoff
   - erosion
   - waste disposal

See page 3-21 of coursebook.

b. Exotic Species Invasion

1. Nuisance plants
2. Nuisance animals

See page 3-21 of coursebook.

c. Lake Use/Management

1. User impacts
2. Management impacts

DETERMINING APPROPRIATE LAKE USES

Range of Uses

In a general sense, there are eleven possible uses of lake water:

1. Contact recreation
2. Passive uses/aesthetics
3. Non-power boating
4. Power boating/skiing
5. Fishing
6. Hunting
7. Consumptive supply
8. Power supply
9. Cooling supply
10. Flood control
11. Ice sports

Establishing Priorities

Three steps are necessary in this process:

1. Assessing the reasonable/practicable uses of the lake, based on lake and watershed features
2. Assessing the needs and desires of the user populations, including non-human elements
3. Building concensus toward an acceptable priority of uses and management framework

As mentioned previously, this is best accomplished from a regional perspective. It would seem foolish to attempt to establish power boating and waterskiing in a shallow lake loaded with stumps when there is a large, deep lake nearby. It is not logical to turn a heavily used pond within the flyway of major waterfowl migrations into a potable water supply facility. On the other hand, it is important to consider the demand for various uses within an area, and to try to satisfy that demand in a rational manner.

The tough part is building a concensus; fish and waterfowl do not vote in most towns, laws that protect wetlands and water quality rarely consider recreational use demand, and lake users frequently fall into tightly defined special interest groups (i.e., user categories like swimmers, boaters, or anglers).

The Delphi process (Delbecq et al. 1975) is an iterative process for achieving concensus within a group selected to represent a cross section of users and managers, and is often more successful than large scale user surveys or town/regional meetings. In any process, it is critical to supply accurate, unbiased information to all concerned parties and to listen carefully to their perspective on the relevant issues.

TABLE 3.7

EFFECTS OF LAKE AND WATERSHED FEATURES ON LAKE USES

(++ = Direct positive relation, + = Indirect positive relation, -- = Direct negative relation,
- = Indirect negative relation, 0 = no clear relation, * = complex relation; e.g. bell curve)

	LAKE USE						
LAKE FEATURES	Consumptive Supply	Contact Recreation	Passive Uses + Aesthetics	Non-power Boating	Power Boating	Fishing	Ice Skating and Boating
Water clarity	++	++	++	++	++	-	0
Dissolved oxygen	+	+	+	0	0	++	0
Temperature	0	++	0	++	++	*	-
pH	*	*	*	0	0	*	0
Fertility	-	-	*	-	-	+	0
Toxic substances	--	--	-	-	-	--	0
Fecal bacteria	--	--	0	-	-	0	0
Macrophyte cover	-	--	*	--	--	*	0
Plankton abundance	--	--	--	-	-	+	0
Panfish abundance	-	-	*	0	0	++	0
Gamefish abundance	+	+	+	0	0	++	0
Waterfowl	-	-	*	0	0	0	0
Lake area	+	++	0	++	++	++	++
Mean depth	+	-	0	0	++	0	-
Maximum depth	+	0	0	0	0	+	0
Lake volume	++	0	0	0	0	+	0
Fetch	-	-	0	*	++	0	+
Shoreline development	0	+	++	+	-	0	*
Detention time	--	*	*	0	0	0	+
Organic hydrosoils	-	-	0	0	0	0	0
WATERSHED FEATURES							
Watershed:lake area ratio	*	-	-	0	0	0	0
Access to lake	-	++	*	*	*	*	++
Shoreline dwellings	-	-	--	0	-	0	0
Soil permeability	*	+	+	0	0	0	0
Land slopes	*	-	0	0	0	0	0
Urbanization	-	-	--	0	0	-	-
Agriculture	-	-	--	0	0	*	0
Logging	*	-	--	0	0	0	0
Hardwood:softwood ratio	*	0	0	0	0	0	0

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.8

EFFECTS OF LAKE USES ON LAKE FEATURES

(++ = Direct positive relation, + = Indirect positive relation, -- = Direct negative relation,
- = Indirect negative relation, 0 = no clear relation, * = complex relation; e.g. bell curve)

	LAKE USE						
LAKE FEATURES	Consumptive Supply	Contact Recreation	Passive Uses + Aesthetics	Non-power Boating	Power Boating	Fishing	Ice Skating and Boating
Water clarity	0	--	0	0	--	0	0
Dissolved oxygen	0	0	0	0	0	0	0
Temperature	0	0	0	0	0	0	0
pH	0	0	0	0	0	0	0
Fertility	0	0	0	0	0	0	0
Toxic substances	0	0	0	0	++	0	0
Fecal bacteria	0	+	0	0	0	0	0
Macrophyte cover	0	--	0	0	*	0	0
Plankton abundance	0	0	0	0	0	*	0
Panfish abundance	0	0	0	0	0	+	0
Gamefish abundance	0	0	0	0	0	--	0
Waterfowl	0	0	0	0	--	0	0
Lake area	--	0	0	0	0	0	0
Mean depth	--	0	0	0	0	0	0
Maximum depth	--	0	0	0	0	0	0
Lake volume	--	0	0	0	0	0	0
Fetch	--	0	0	0	0	0	0
Shoreline development	0	0	0	0	0	0	0
Detention time	--	0	0	0	0	0	0
Organic hydrosoils	0	0	0	0	0	0	0

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

TABLE 3.9

EFFECTS OF LAKE USES ON OTHER LAKE USES

(++ = Direct positive relation, + = Indirect positive relation, — = Direct negative relation,
- = Indirect negative relation, 0 = no clear relation, * = complex relation; e.g. bell curve)

(All effects are read as the effect of the vertically listed (Y-axis) use on the horizontally listed (X-axis) use)

	LAKE USE						
LAKE USE	Consumptive Supply	Contact Recreation	Passive Uses + Aesthetics	Non-power Boating	Power Boating	Fishing	Ice Skating and Boating
Consumptive Supply	X	-	-	-	-	*	-
Contact Recreation	—	X	-	--	—	--	0
Passive Uses + Aesthetics	0	0	X	0	0	0	0
Non-power Boating	-	--	-	X	-	-	0
Power Boating	-	--	-	--	X	-	0
Fishing	0	—	0	0	0	X	-
Ice Skating and Boating	-	-	*	-	-	0	X

Source: Baystate Environmental Consultants, Longmeadow, Massachusetts.

LAKE PROBLEMS AND THEIR IDENTIFICATION
WORKSHEETS

WORKSHEET: IDENTIFICATION OF AQUATIC PROBLEMS

Lake /Pond Name:
Region:
Investigator:
Date:

What management problems exist: (please check)

Excessive algal growth ______
Excessive weed growth ______
Turbidity ______
Fish kills ______
User conflicts ______
Poor water quality ______
Poor Fishing ______
Leeches ______
Lack of control over watershed activities ______
Anaerobic summer conditions ______
Closed swimming areas ______
Other? ____________________ ______

Describe existing and anticipated aquatic management problems:

SECTION 4.

DEVELOPMENT OF A LAKE MANAGEMENT PLAN

DEVELOPMENT OF A LAKE MANAGEMENT PLAN

See Section 4 of the coursebook for a discussion of lake management plans.

Lake management methods may be divided into in-lake and watershed controls. For the purposes of this section, the term watershed will include the surface watershed and ground-water recharge areas. Choice of a method depends upon the site-specific characteristics of each lake, as well as its cost and availability, aesthetics, and personal preferences. Each control method is appropriate to a particular set of circumstances. Therefore, the particular characteristics of each site must be considered when selecting a remediation method.

Typically a combination of both in-lake and watershed measures provides the most effective strategy. Treating the in-lake symptoms does not necessarily rid a lake of its problems, since the cause of the problem may be in the watershed. Likewise, treating the cause of the problem in the watershed may eliminate the in-lake symptoms. For example, nutrient fluxes from sediments within the lake may be sufficient to maintain eutrophic conditions, even after minimizing nutrient loading from the watershed.

IN-LAKE MANAGEMENT TECHNIQUES

Physical Techniques

See page 4-7 through 4-20 of coursebook.

1. Benthic Screening
2. Lake Level Drawdown
3. Dredging
4. Harvesting
5. Hydroraking
6. Aeration
7. Hypolimnetic Aeration
8. Hypolimnetic Withdrawal
9. Sediment Oxidation
10. Dilution and Flushing
11. Artificial Circulation

Biological Techniques

See page 4-20 through 4-23 of coursebook.

1. Grass Carp
2. Pathogens
3. Insect Pests
4. Food-Chain Manipulation

Chemical Techniques

See page 4-23 through 4-28 of coursebook.

1. Herbicides and Algicides
2. Alum
3. Dye

WATERSHED MANAGEMENT TECHNIQUES

Historically, communities throughout Massachusetts have relied upon local bylaws and regulations to protect water resources from both point source (direct discharge such as sewage outfall pipes) and non-point source (stormwater discharge from catch basins or septic systems) contamination. Although these regulatory tools are typically adopted and implemented on the community level, many of these tools are directly applicable to the DEM. Some may also be adopted as park regulations (such as phosphorus detergent bands).

In cases where the DEM only controls land activities in a portion of a lake's watershed, the greatest means of watershed protection may be at the community level. In this case, DEM staff may assist local communities in adopting these controls. Many of the subdivision regulations, health regulations and wetland regulations affect activities at the site level (i.e. waterways buffers, underground fuel tanks, septic system placement etc.). These controls are intended to minimize water degradation resulting from improper site design. These site design controls are as applicable to the DEM as to private land developers, and should be followed when designing and managing parks. Figure 4.1 presents the lake and pond watershed management techniques discussed in this section. The following is a list of the

various tools available to communities for lake protection.

Regulatory

Zoning

See page 4-29 through 4-36 of coursebook.

1. Overlay Ground and Surface Water Protection Districts
2. Prohibition of Various Land Uses
3. Special Permitting
4. Large Lot Zoning
5. Site Plan Review
6. Waterway Buffers
7. Performance Standards
8. Transfer of Development Rights
9. Cluster Design

Subdivision Control Rules and Regulations

See page 4-36 and 4-37 of coursebook.

1. Drainage Requirements
2. Performance Standards/Nitrogen Loading

Health Regulations

See page 4-37 through 4-39 of coursebook.

1. Underground Fuel Storage Systems.
2. Privately-Owned Wastewater Treatment Plants (Small Sewage Treatment Plants).
3. Phosphorus Buffer Zone.
4. Septic Cleaner Ban.
5. Septic System Maintenance.
6. Sewage System Upgrades

Wetland Bylaws

See page 4-39 through 4-41 of coursebook.

1. Natural Vegetated Buffers
2. Surface Water Discharges
3. Erosion and Sedimentation Control
4. Restrictions on Pesticides and Fertilizers

Non-Regulatory Techniques

See page 4-42 through 4-44 of coursebook.

Although many non-regulatory water resource programs are available to cities and towns in New England, they have traditionally focused on four categories:

1. Donations
2. Taxation Deferments
3. Conservation Easements
4. Outright Sale of Land

Legislative Techniques

See page 4-44 through 4-46 of coursebook.

Legislative growth management strategies include those created by individual state legislative bodies. As local governments do not possess inherent sovereign power, their jurisdiction rests almost exclusively with state constitutional provisions, charters, statutes, ordinances and regulations. Legislative growth management strategies focus on approaches that states deem appropriate for state-wide or regional land management.

Park Watershed Management Techniques

See page 4-46 through 4-74 of coursebook for a review of park management options.

1. Site Design

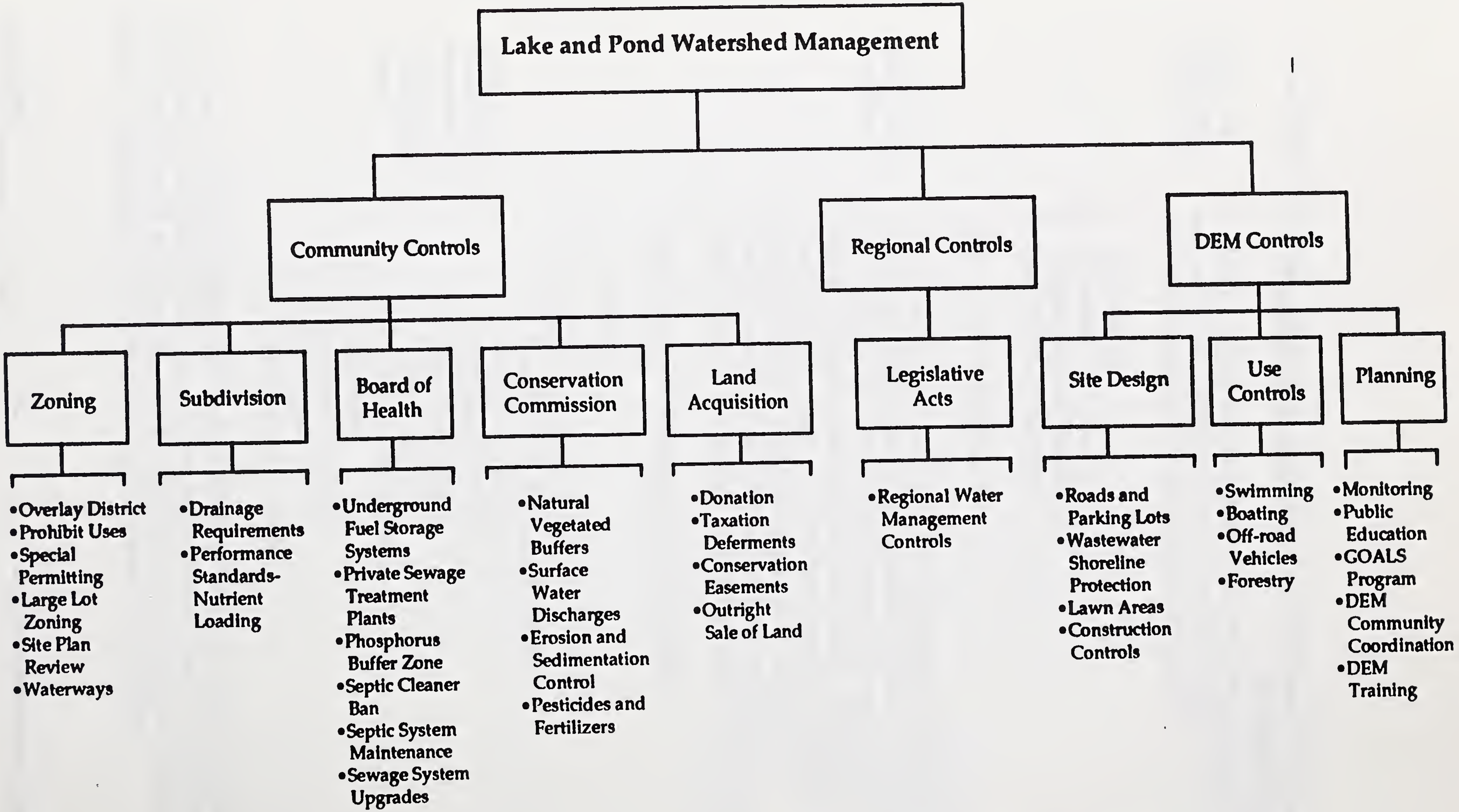
    a. Roads and Parking Lots
        - Detention and Retention Ponds
        - Infiltration Basin
        - Infiltration Trench
        - Porous Pavement
        - Grassed Swales
        - Constructed Wetlands

    b. Wastewater
    c. Shoreline Protection
    d. Lawn Areas
    e. Construction Controls

A summary of the pollution reduction benefits of various runoff control structures is provided in Chapter 2 of the book, "Controlling Urban Run-off: A Practical Manual for Planning and Designing Urban BMPs" by Thomas Schueler, Department of Environmental Programs, Metropolitan

Washington Council of Governments. A copy of this section is included in this course manual.

FIGURE 4.1 Watershed Management Techniques



This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

IN-LAKE RESTORATION TECHNIQUES

Technique	Advantages	Drawbacks	Cost	Term of Effectiveness
1. PHYSICAL CONTROL				
Aeration (P,A,H,F)	Increased oxygen Restores cold-water fisheries Improved taste/odor Reduced nutrient release	Only lakes with large hypolimnion nutrient diffusion from bottom to top	C=$$$ O=$$$	Delayed; Duration unknown
Artificial Circulation (P,A,H)	Reduced internal N,P,Fe,Mn cycling Increased oxygen Change from blue-green to green algae	Increased particulate nutrients Decreased clarity Temperature increase in hypolimnion	C=$$ O=$	Slightly delayed; Duration unknown
Bottom Barriers (P)	Very effective Environmentally safe Easy installation for small areas	Difficult installation for large/steep area Degradable materials Regrowth thru/on top Difficult to move/secure	C=$$$ O=$$	Immediate; Long-term with proper control
Dilution/Flushing (A)	Algae washout Reduced nutrients	Large quantity of low nutrient water needed for dilution	C=$ O=$	Immediate; Continuous use necessary
Diver Dredging (P,T)	Removes whole plant/nutrients Selective No waiting period	Very slow Disturbs sediment and clarity	C=$ O=$$$	Immediate; Repeated continuously
Hypolimnetic Withdrawal (P,A,H)	Reduced lake P,N Increased bottom oxygen levels Increased clarity	Degradation of receiving waters Destratification	C=$$ O=$	Slightly delayed; Potentially long-term
Mechanical Harvesting (P)	Easily controlled Low impact on ecosystem No post-treatment waiting Some P,N removal	Not selective Slow Limited area of treatment or effectiveness Fragmentation	C=$$$ O=$$	Immediate; Repeated up to several times per year
Rotovating (P)	Easily controlled No waiting period Some P,N removal	Depth limits Slow Disturbs sediment Fragmentation	C=$$$ O=$	Immediate; Repeated up to several times per year

Source: New York State Department of Conservation and Federation of Lake Associations, 1990.

IN-LAKE RESTORATION TECHNIQUES *(continued)*

Technique	Advantages	Drawbacks	Cost	Term of Effectiveness
		1. PHYSICAL CONTROL (cont)		
Sediment Removal (P,S,T)	Removes plants and sediment Increases depth Reduces internal nutrient cycling Very effective	May spread toxics in sediment/spoils Difficult disposal Short-term Turbidity, Algae bloom, low DO, post-monitoring needed	C=$$$ O=$$$	Slightly delayed; Control for several years
Shading (P,A)	Non-toxic No recreational waiting period	Restricted in potable water supplies Non-target control Little evidence of long-term effects	C=$ O=$	Slightly delayed; Duration unknown Depends on retention time
Water Level Control/Drawdown (P,S)	Consolidate bottom sediments Fish management Helps other mgmt. techniques	Enhances some plants Poor in seepage lakes Algal blooms possible Refill problems Must have freezing and desiccation	C=$ O=$	Slightly delayed; Repeated yearly for several years
		2. CHEMICAL CONTROL		
Algicides (A,H)	Simple application No/low human toxicity	DO depletion with fish kills Zooplankton toxicity and algal "rebound" Blue-green algae tolerance May be ineffective	C=$ O=$	Immediate; Repeated up to several times yearly
Herbicides (P)	Species specific Often effective	Nutrient release with DO depletion Non-target toxicity Target plants replacing non-target plants Dangerous application Public perception	C=$ O=$$	Immediate; Repeated yearly or more often

Source: New York State Department of Conservation and Federation of Lake Associations, 1990.

IN-LAKE RESTORATION TECHNIQUES *(continued)*

Technique	Advantages	Drawbacks	Cost	Term of Effectiveness
		2. CHEMICAL CONTROL (cont)		
Liming (AC)	Restores acceptable pH, alkalinity; Restocking possible	Aluminum toxicity Lime handling and pH "hot spots" Perception of organic alkalinity	C=$$ O=$$	Immediate; Duration unknown Depends on lake characteristics
Precipitation and Inactivation (A,T)	Reduces internal nutrient cycling Increased clarity Reduced intensity/ duration of algae blooms	Toxic/pH effects from aluminum salts Weed growth from increased clarity Only stratified lakes	C=$$ O=$	Immediate; Potentially long-term control
Sediment Oxidation (A,T)	Chemicals confined Sediment promotes organic matter decay Low toxicity	Relatively untested Ineffective in shallow lakes with high bottom pH	C=$$ O=$	Immediate; Potentially long-term control
		3. BIOLOGICAL CONTROL		
Food Web Manipulation (A,F)	"Natural" control May improve clarity Can introduce desired species	May effect non-target species in web Algal "rebound" Potentially large unknown effects	C=$$ O=?	Delayed; Duration unknown
Grass Carp (P)	Slow control No chemicals or machinery needed Selective control possible	Understocking may control only native plants Overstocking may eradicate plants and damage ecosystem Fish may escape and affect non-target lakes and streams	C=$$ O=$	Delayed; Potentially long-term control
Research Projects: Plant Pathogens, Aquatic Insects (P)	"Natural" control Can target specific plants and areas Slow control	Unknown effects Non-target areas may be affected Limited to warm climate	C=$ O=$	Delayed; Duration unknown Potentially long-term

Source: New York State Department of Conservation and Federation of Lake Associations, 1990.

IN-LAKE RESTORATION TECHNIQUES *(continued)*

Technique	Advantages	Drawbacks	Cost	Term of Effectiveness
4. INSTITUTIONAL CONTROL				
Dock/Mooring Regulations (T,C)	May effectively reduce traffic Reduces pollution from chemically-treated docks	May be unpopular with residents May result in shorter dock life	C=NA O=NA	Immediate; Potentially long-term
Fisheries Regulations (F)	Reduces fishing pressures Improves survival of sensitive species	May be unpopular with residents Difficult to enforce	C=NA O=NA	Delayed; Potentially long-term
Navigation Rules (C)	Mandated through legislation Doesn't restrict actual boating Equitable	Difficult to enforce May be unpopular with many active residents	C=NA O=NA	Immediate; Potentially long-term
Creating/Limiting Public Access (C)	Controls level of activity Restricts activity for specific user groups Restricts use to tax/fee payers	May restrict income base May limit available local, State or Federal funding	C=NA O=NA	Immediate; Potentially long-term
Lake Zoning (C)	Reduces user conflicts Can facilitate compliance with navigation laws	May not please all user groups May be difficult to enforce	C=NA O=NA	Immediate; Potentially long-term

Legend for Table:

Technique: (bold letter addresses the following problems)
P - Nuisance aquatic plants (macrophytes)
A - Nuisance algae (phytoplankton)
S - Suspended sediment or silt
T - Toxic or hazardous materials
H - Bacteriological, taste, odor or other health-related problems
F - Fisheries restoration
AC - Acidified conditions
C - Crowding conditions (boaters, fishermen, swimmers, or other recreational use)

Cost:
C = capital expense
O = operational expense (one application or a single season of use, whichever is longer)
$ = low cost $$ = medium cost $$$ = high cost

Source: New York State Department of Conservation and Federation of Lake Associations. 1990. Diet for a Small Lake. A New Yorker's Guide to Lake Management. Albany, NY.

TABLE 4.1 IN-LAKE MANAGEMENT DECISION SELECTOR

This form is intended to aid in the evaluation of a particular management technique.

PREPARED BY LEE LYMAN

LYCOTT ENVIRONMENTAL RESEARCH, INC

CATAGORY	DREDGE		DRAWDOWN FLUSHING		AERATION		HERBICIDE		ALGAECIDE		HARVEST		HYDRO-RAKE		SEDIMENT TILLING		HYPO-LIM WITHDRAWEL		BENTHIC SCREEN		SEDIMENT OXIDATION		BIOLOGICAL		ALUM		DYE		DILUTION		ARTIFICIAL CIRCULATION		FOOD CHAIN MANIPULATION	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
OUTLET STRUCTURE ADEQUATE	5		10		1		3		3		1		1		1		8		1		1		9		3		10		5		5		1	
PRIVATE WELLS	10		10		1		6		4		2		2		2		1		1		1		1		1		7		1		1		1	
ASSOCIATED WETLANDS	9		8		1		2		1		1		3		1		1		1		1		2		1		1		1		3		1	
IMPACTS TO FISHERIES	10		8		7		3		2		8		10		10		8		8		8		10		3		2		8		10		10	
AMPHIBIANS	10		9		1		1		1		6		8		6		1		6		1		6		1		1		2		10		3	
MUSSELS	10		10		3		1		1		1		10		10		2		10		10		2		1		1		4		10		2	
CRAWFISH	10		8		1		1		1		1		10		10		1		10		8		7		1		1		4		10		3	
BENTHICS	10		10		1		2		4		3		10		10		2		10		10		8		1		1		7		10		3	
WATER FOWL	10		6		1		1		1		1		3		1		1		1		1		1		1		1		1		2		1	
PUBLIC DRINKING WATER SUPPLIES	10		8		1		10		10		5		5		5		1		1		5		3		1		1		1		1		1	
HYDROLOGY BUDGET	10		10		1		8		6		2		2		2		8		1		2		2		10		10		10		1		1	
EXPOSURE OF MOST AQUATIC PLANTS	8		10		1		8		1		8		8		8		1		8		1		8		1		1		1		2		1	
DISRUPTION OF RECREATIONAL ACTIVITIES	10		10		1		4		3		3		4		1		1		1		1		5		2		1		3		5		1	
IMPACTS TO NON-TARGET ORGANISMS	10		8		1		2		3		5		10		10		1		10		10		8		1		1		4		10		5	
SELECTIVITY FOR SPECIFIC AREAS OF POND	1		2		1		10		1		8		10		10		1		10		1		1		1		1		1		10		1	
SPECIES SPECIFIC	1		1		1		9		9		2		4		1		1		1		1		4		9		1		1		1		4	
LONGTERM EFFECTIVENESS	5		10		3		6		2		1		4		2		4		2		2		8		6		1		8		3		5	
TYPE OF POND BOTTOM	10		8		1		1		1		8		10		10		2		10		10		2		1		1		1		10		2	
DOWN STREAM EFFECTS	10		8		1		2		2		2		2		1		4		1		2		4		1		10		10		5		3	
AGRICULTURAL USE	10		8		1		10		8		1		2		2		8		1		2		3		1		3		5		1		2	
PERMITTING	10		5		2		8		7		3		3		4		2		1		3		10		2		6		5		3		4	
CONSERVATION COMMISSION	10		10		1		10		10		10		10		10		5		10		10		10		10		10		10		10		2	
DEP																																		
LAKES PERMIT/LICENSE	1		10		1		10		10		1		1		1		1		10		1		1		10		10		1		1		1	
DIV WATERWAYS	10		1		1		1		1		1		1		5		1		1		1		1		1		1		10		1		1	
WATER QUALITY CERTIFICATE	10		1		1		1		1		1		1		5		5		1		1		1		1		1		10		1		1	
WETLANDS	10		10		1		8		10		10		10		10		1		10		1		10		10		10		5		1		1	
PESTICIDE BOARD LICENSE	1		1		1		10		1		1		1		1		1		1		1		1		10		10		1		1		1	
ARMY CORPS OF ENGINEERS	10		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1	
FISHERIES & WILDLIFE	10		10		5		1		1		1		1		1		1		1		1		10		1		1		5		1		10	
MEPA	10		2		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1	
COST HIGH (H), MODERATE (M), LOW (L)																																		
INITIAL	H		M		H		M		L		M		H		H		H		H		H		M		M		H		H		H		M	
ANNUAL	L		L		M		M		L		M		M		M		L		H		H		M		M		H		M		H		L	
PER ACRE	H		L		H		L		L		M		M		M		M		H		H		M		L		H		M		H		L	

NOTE:• "1" IS NOT APPLICABLE OR SIGNIFICANT. "10" IS HIGHLY APPLICABLE OR SIGNIFICANT.

• THE COLUMN "G", IS A GENERAL EVALUATION DEVELOPED BY LEE LYMAN BASED ON 25 YEARS OF EXPERIENCE

• THE COLUMN "S", IS INTENDED TO BE FILLED OUT BY THE USER FOR A SPECIFIC LAKE.

TABLE 4.2 Watershed Management Impacts

Watershed Management Technique	Reduce Loading of Suspended Solids	Reduce Loading of Nutrients	Reduce Metals and Organic Materials	Improve Wildlife Habitat	Risk of Well Contamination
Stormwater Management:					
Grassed Swales	++	+	++	0	-
Infiltration Basin	++	++	++	0	--
Infiltration Trench	++	++	++	0	--
Porous Pavement	++	++	++	0	-
Detention Pond*	+++	+	++	+	+
Retention Pond*	+++	++	++	++	++
Constructed Wetland	+++	+++	+++	+++	+++
Wastewater Management:					
Septic System Siting and Maintenance	0	+	0	0	++
Wastewater Performance Standards	0	+++	0	0	+++
Small Sewage Treatment Plants	0	+++	0	0	-
Composting Toilets	0	+++	0	0	++
Solar Aquatics	0	+++	0	0	++
Shoreline Protection:	+++	+++	+++	+++	0
Lawn Area Best Management:	+++	++	+++	+	+
Construction Controls:	+++	0	+	0	0

Key:

+	low postive impact
++	moderate postive impact
+++	high postive impact
0	no impact or not applicable
-	low negative impact
–	moderate negative impact
—	high negative impact
*	positive impacts may be improved through addition of constructed wetlands

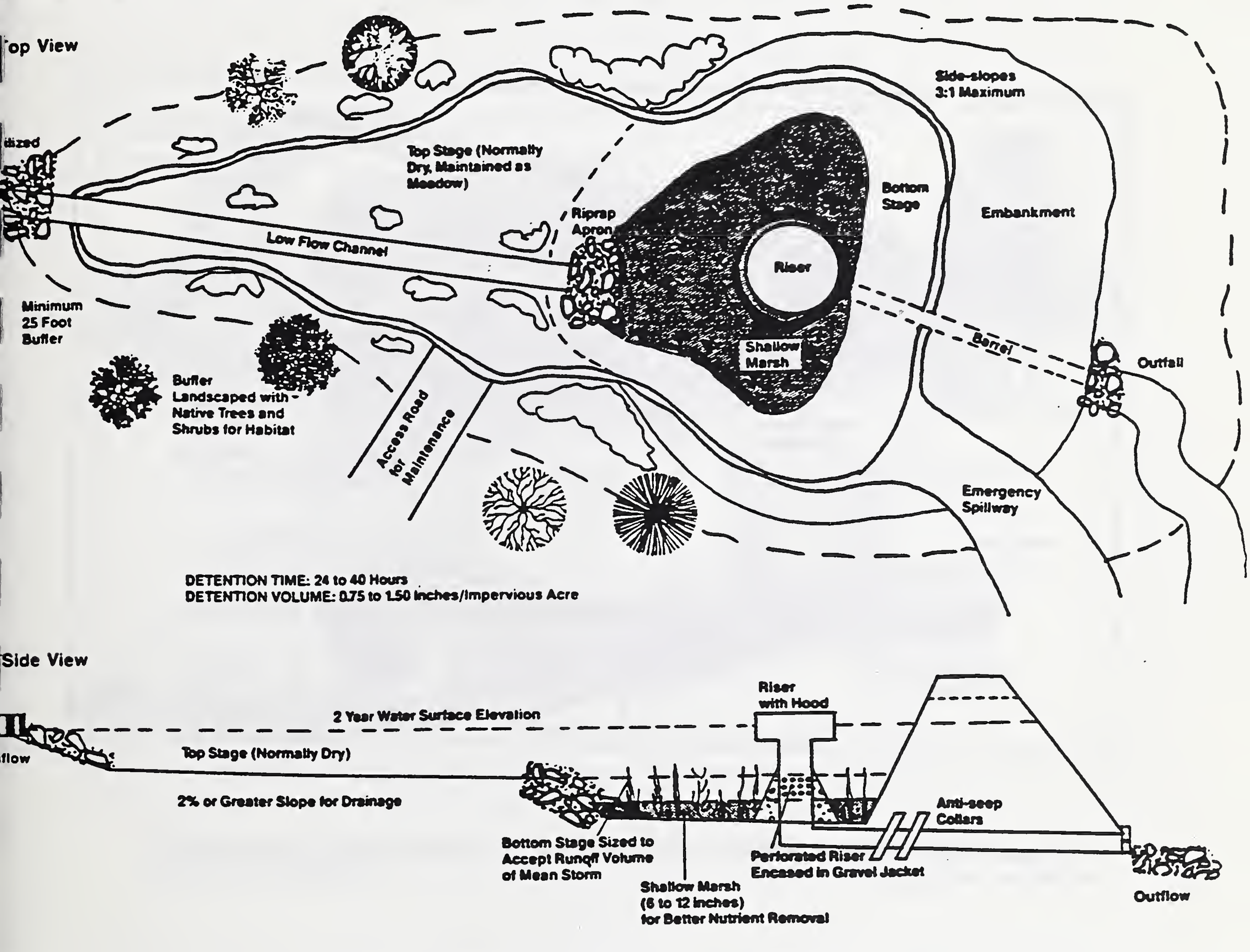
This table is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

TABLE 4.3
Comparative Costs of Stormwater Management Techniques

Technique	Construction Costs	Maintenance Cost	Water Quality Benefits
Grassed Swales	Low	Moderate	Moderate
Infiltration Basin	Moderate-High	High	Moderate-High
Infiltration Trench	Low-Moderate	Moderate-High	Moderate
Porous Pavement	High	High	Moderate
Detention Pond	Low-Moderate	Moderate-High	Moderate-High
Retention Pond	High	Moderate-High	High
Constructed Wetlands	High	Low	High

This table is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

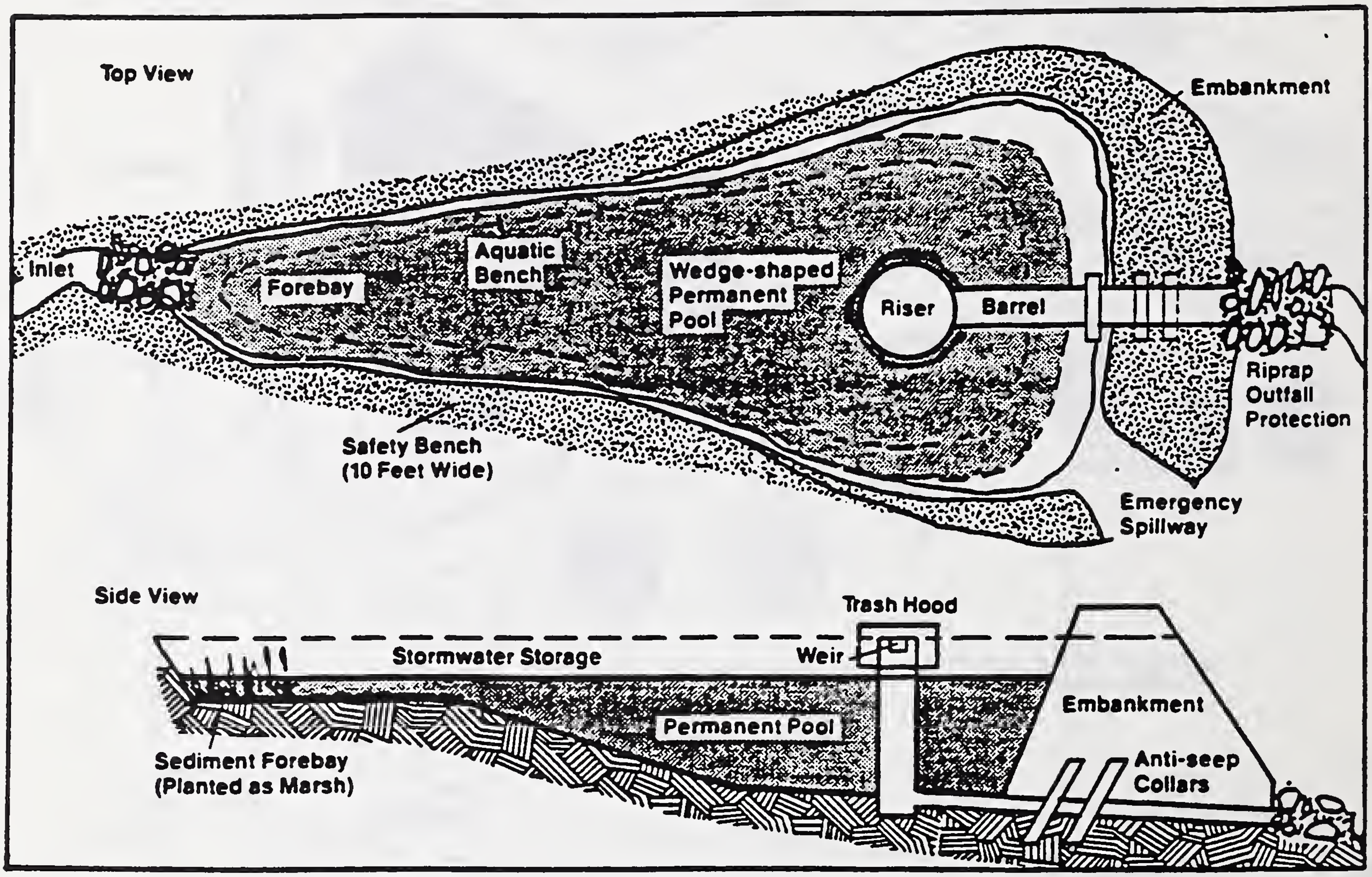
FIGURE 4.3 Schematic of Extended Detention Pond Utilizing a Shallow Marsh


op View
dized
Top Stage (Normally Dry, Maintained as Meadow)
Side-slopes 3:1 Maximum
Bottom Stage
Embankment
Riprap Apron
Low Flow Channel
Riser
Minimum 25 Foot Buffer
Shallow Marsh
Barrel
Outfall
Buffer Landscaped with Native Trees and Shrubs for Habitat
Access Road for Maintenance
Emergency Spillway
DETENTION TIME: 24 to 40 Hours
DETENTION VOLUME: 0.75 to 1.50 inches/Impervious Acre
Side View
Riser with Hood
2 Year Water Surface Elevation
flow
Top Stage (Normally Dry)
2% or Greater Slope for Drainage
Anti-seep Collars
Bottom Stage Sized to Accept Runoff Volume of Mean Storm
Perforated Riser Encased in Gravel Jacket
Shallow Marsh (6 to 12 inches) for Better Nutrient Removal
Outflow

This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

SOURCE: T.Schueler, 1987

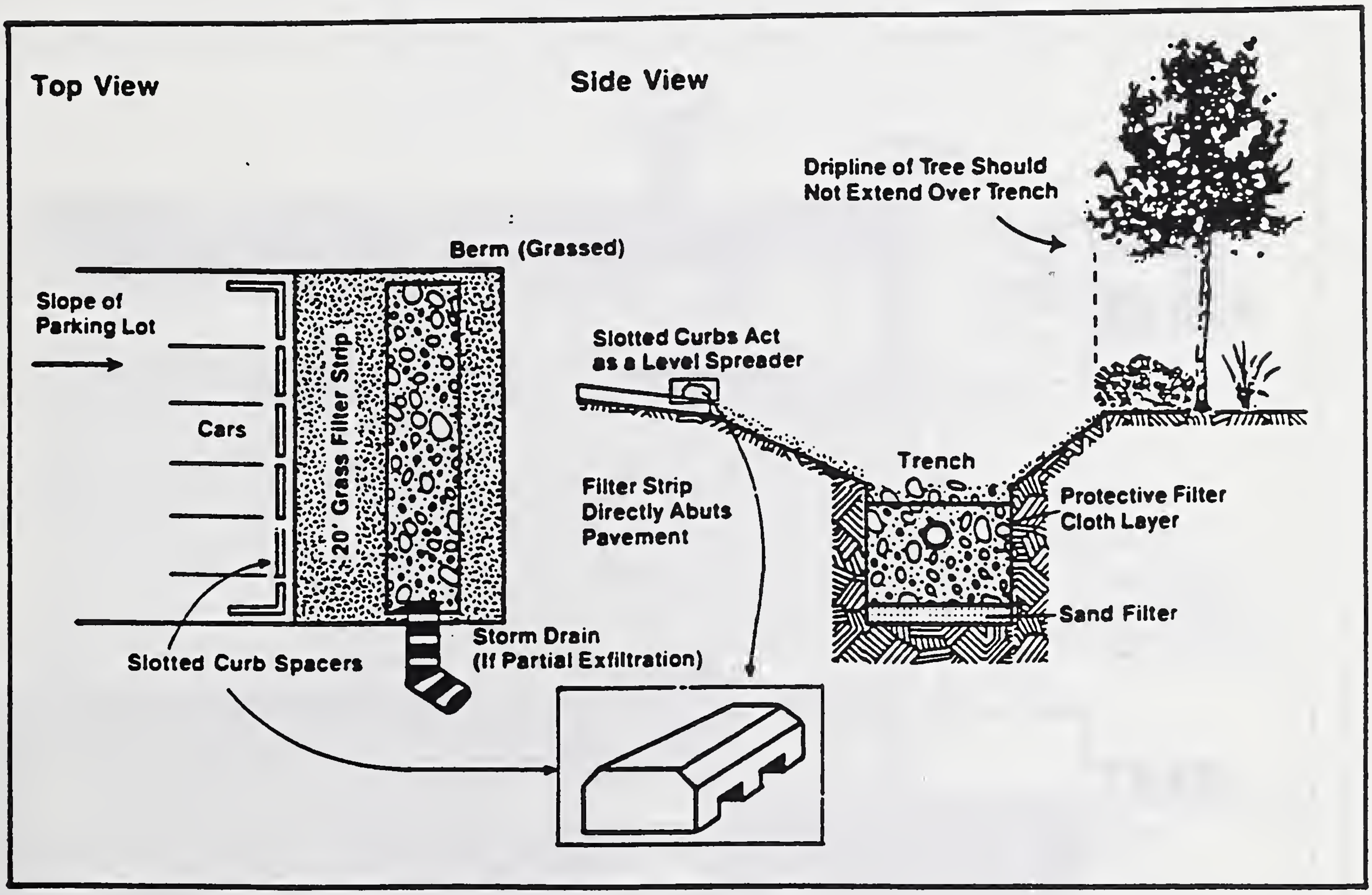
FIGURE 4.4 Schematic of Wet Pond



This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

SOURCE: T.Schueler, 1987

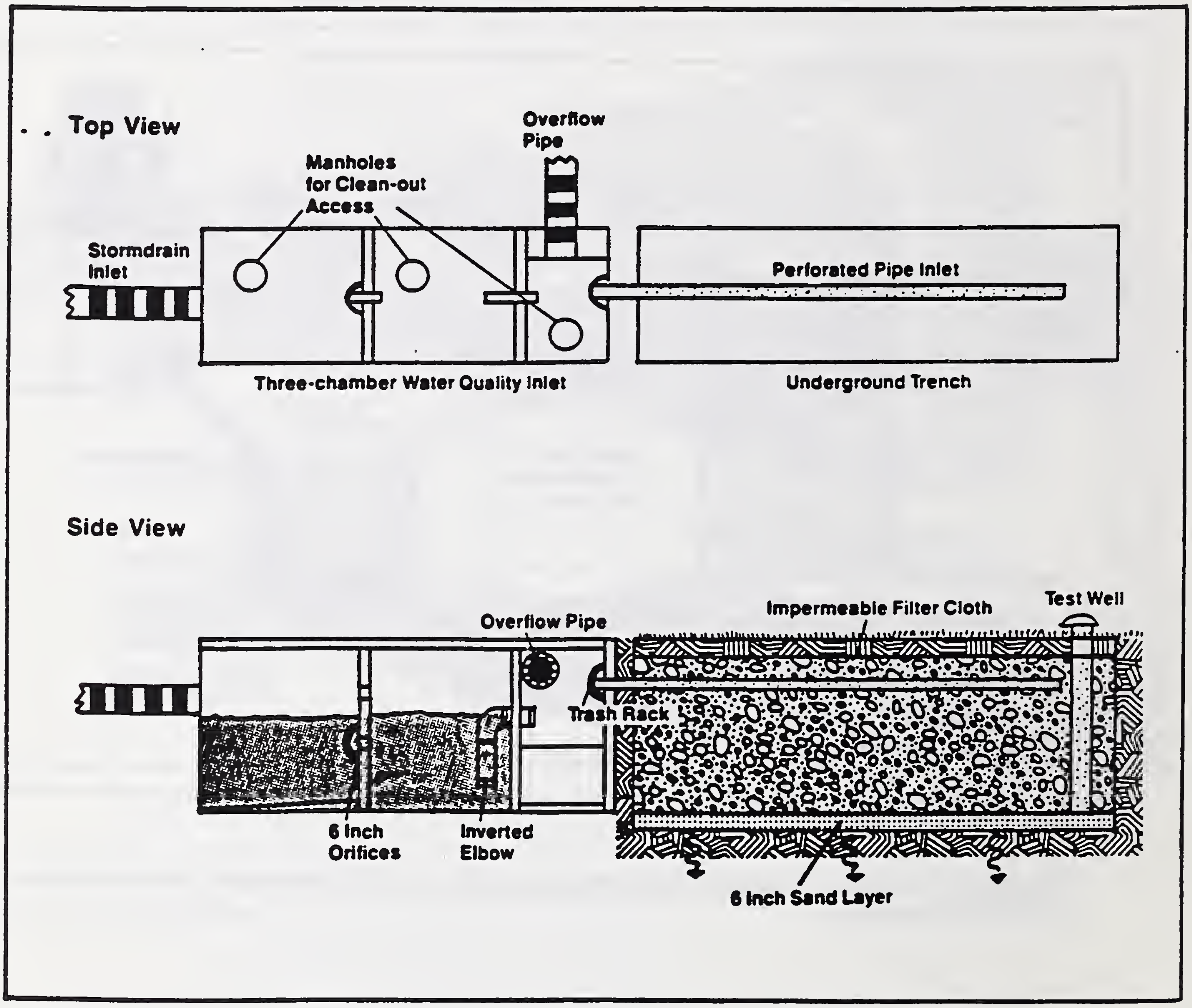
FIGURE 4.8 Schematic of Parking Lot Trench


Top View
Side View
Dripline of Tree Should Not Extend Over Trench
Berm (Grassed)
Slope of Parking Lot
Slotted Curbs Act as a Level Spreader
Cars
20' Grass Filter Strip
Trench
Filter Strip Directly Abuts Pavement
Protective Filter Cloth Layer
Sand Filter
Storm Drain (If Partial Exfiltration)
Slotted Curb Spacers

This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

SOURCE: T.Schueler, 1987

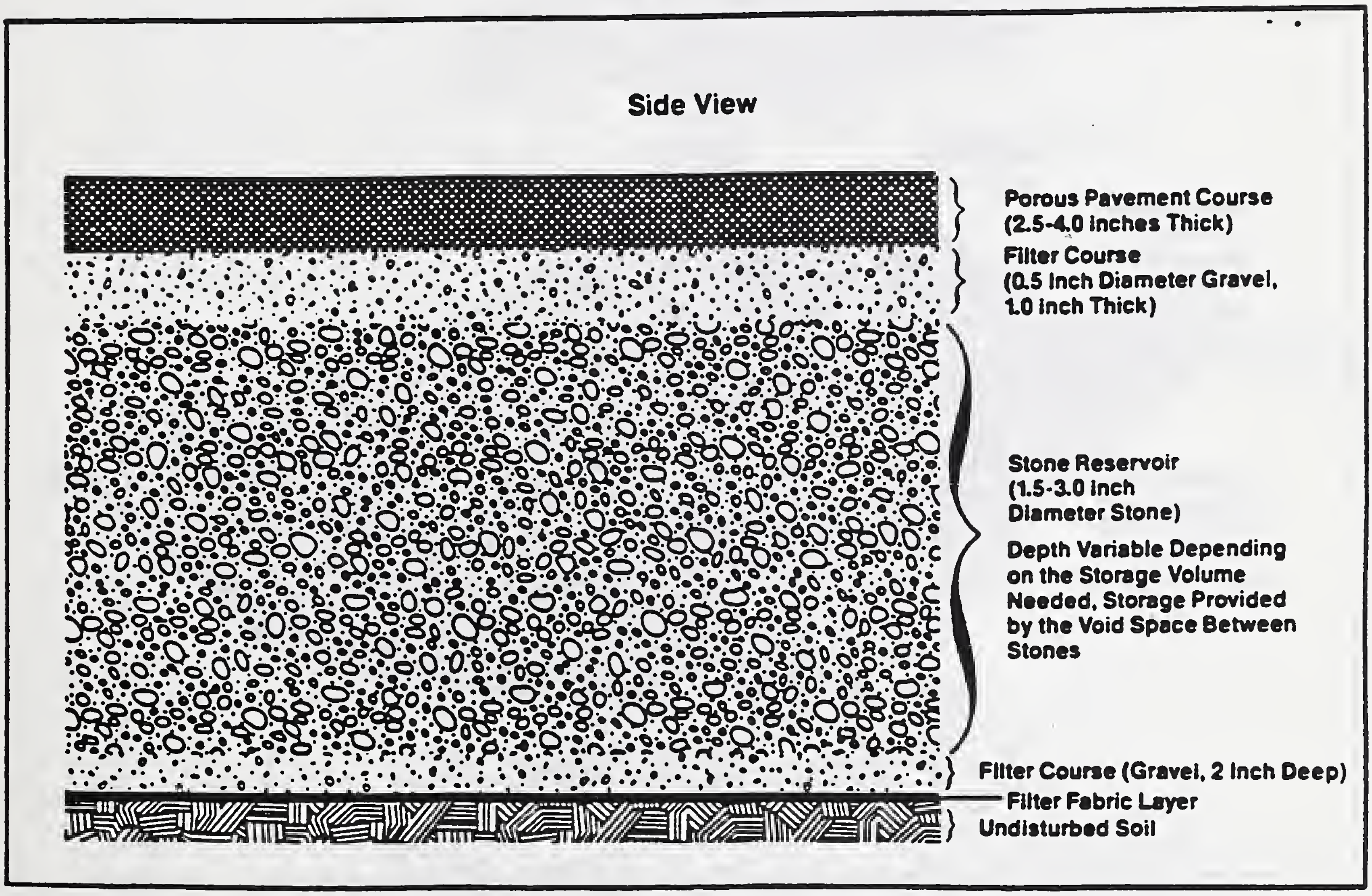
FIGURE 4.9 Schematic of Underground Trench with Oil/Grit Chamber



This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

SOURCE: T.Schueler, 1987

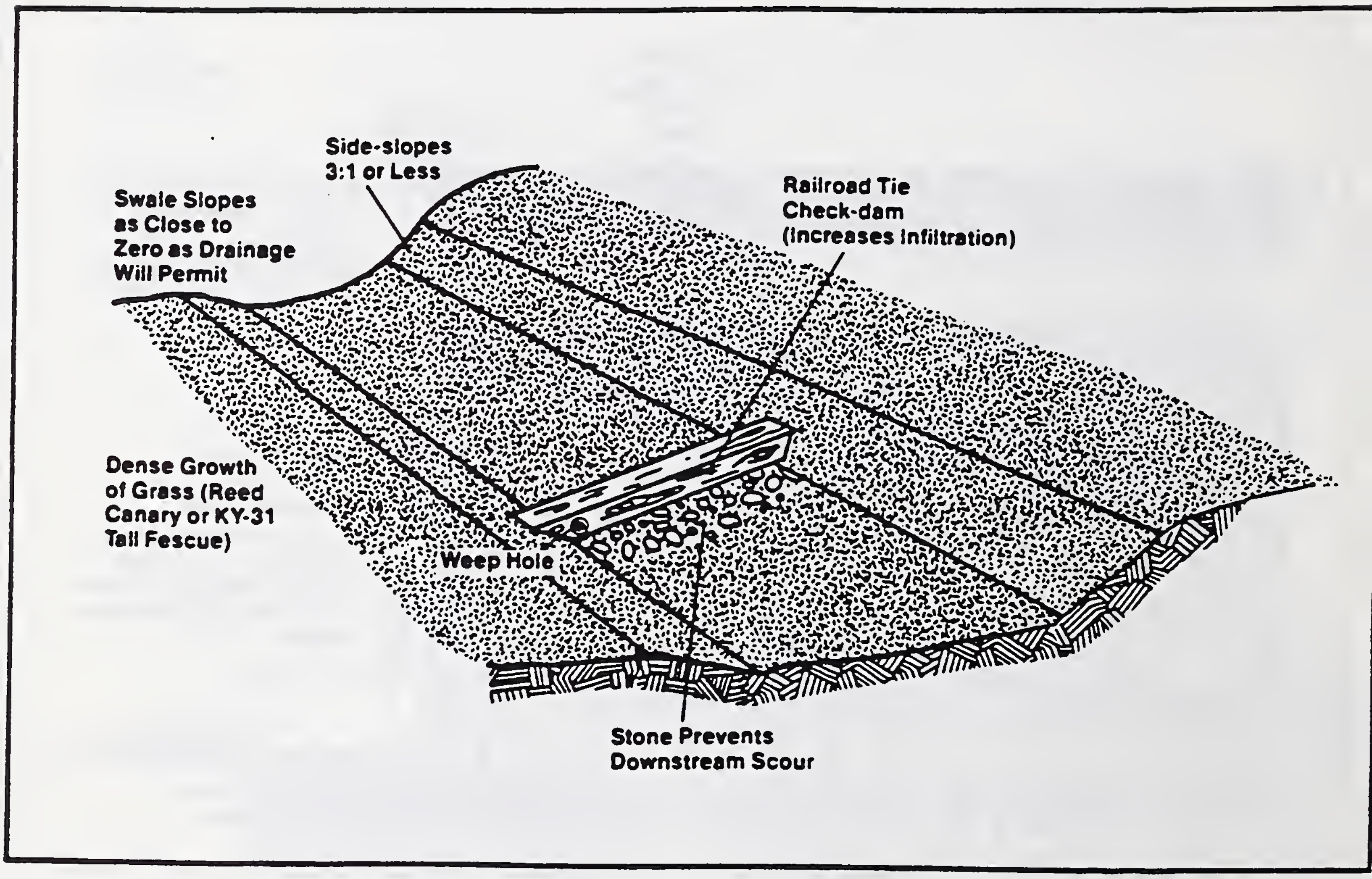
FIGURE 4-10 Schematic of Porous Pavement


Side View
Porous Pavement Course (2.5-4.0 inches Thick)
Filter Course (0.5 Inch Diameter Gravel, 1.0 inch Thick)
Stone Reservoir (1.5-3.0 inch Diameter Stone)
Depth Variable Depending on the Storage Volume Needed, Storage Provided by the Void Space Between Stones
Filter Course (Gravel, 2 Inch Deep)
Filter Fabric Layer
Undisturbed Soil

This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

SOURCE: T.Schueler, 1987

FIGURE 4-11 Schematic of Grassed Swale

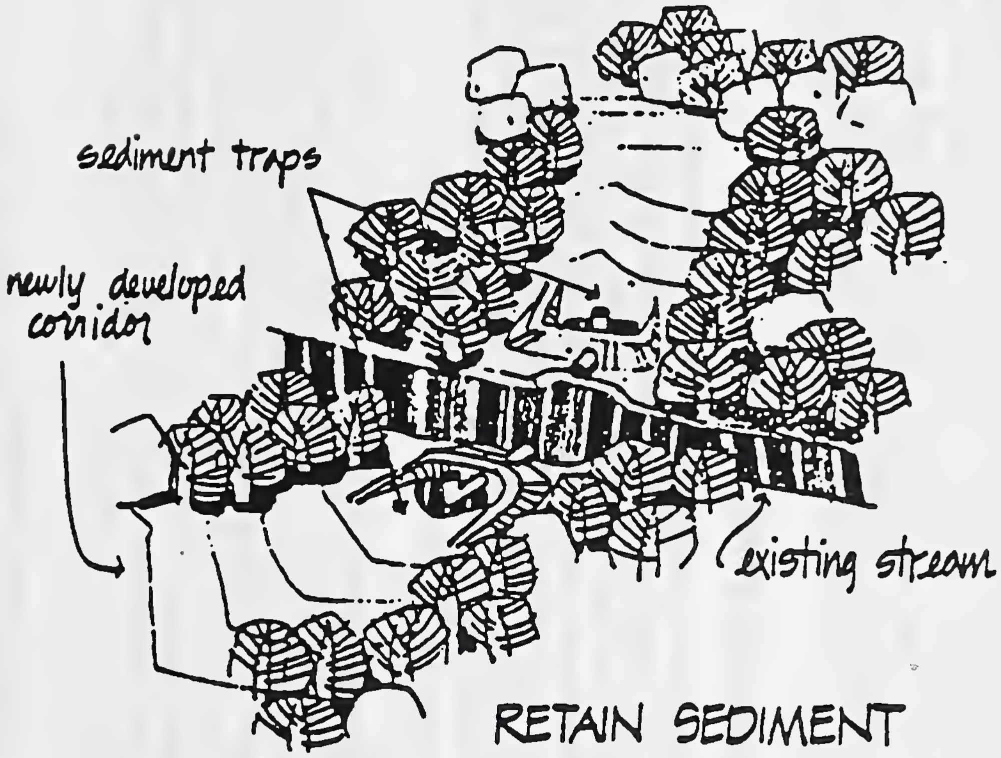

Side-slopes 3:1 or Less
Swale Slopes as Close to Zero as Drainage Will Permit
Railroad Tie Check-dam (Increases Infiltration)
Dense Growth of Grass (Reed Canary or KY-31 Tall Fescue)
Weep Hole
Stone Prevents Downstream Scour

This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

SOURCE: T.Schueler, 1987

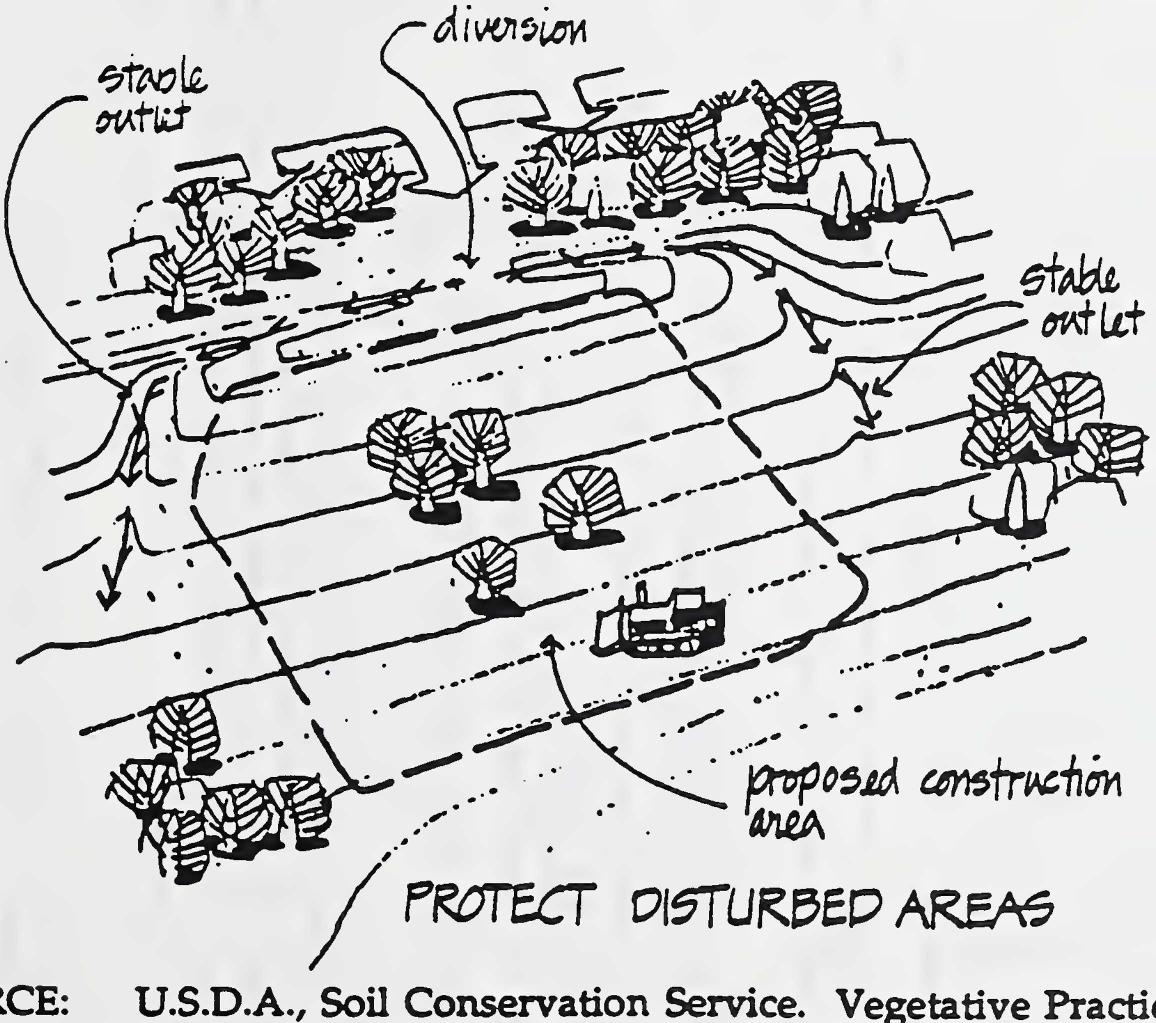
This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

FIGURE 4.14 Sedimentation Control Structures



SOURCE: U.S.D.A., Soil Conservation Service. Vegetative Practices in Site Development. Massachusetts Conservation Guide. Volume II.

FIGURE 4.15 Runoff Diversion during Construction Activities



SOURCE: U.S.D.A., Soil Conservation Service. Vegetative Practices in Site Development. Massachusetts Conservation Guide. Volume II.

ESTIMATING SEPTIC TANK PUMPING FREQUENCY

By Karen Mancl[1]

INTRODUCTION

Septic tank-soil absorption systems are the conventional wastewater treatment systems used in rural areas because of their relatively low cost and limited maintenance requirements. The septic tank's primary purpose is to settle solids from the wastewater, thereby protecting the soil absorption system. Also, it provides for some anaerobic digestion of the retained solids and stores the undigested solids. In time, the storage capacity of the tank will be exceeded and solids will be carried over into the soil absorption system. To prevent this, the tank should be pumped periodically. The necessary frequency of pumping is a question raised by many homeowners. A common answer is once every 1–3 yr, but is this a reasonable answer? By using average values reported in the literature, it is possible to estimate the necessary pumping frequency.

ESTIMATING SLUDGE STORAGE VOLUME

The solids in wastewater settle out of solution in the quiescent environment of the septic tank. Laak concluded, from a study of multichamber septic tanks, that an efficient tank should provide at least a 24-hr liquid detention time (2). The remaining volume of the tank is available for sludge storage. The volume needed to provide 24 hr of liquid detention time can be estimated for any household size given a daily water use of 50 gal/person (0.19 m^3/person). The volume available for sludge storage would be the remainder of the tank.

$$\text{Sludge Storage Vol.} = \begin{matrix}\text{Size of}\\ \text{tank}\end{matrix} - \frac{50\ \text{gal}}{\text{person}\cdot\text{day}} \times \begin{matrix}\text{No. of}\\ \text{people}\end{matrix} \times \begin{matrix}\text{1 day liquid}\\ \text{detention time}\end{matrix} \quad \ldots\ldots\ldots\ldots \quad (1)$$

For example, for a 900 gal (3.4 m^3) tank that serves 6 people, 600 gal (2.3 m^3) would be available for sludge storage. The same tank serving 2 people would have 800 gal (3.0 m^3) of sludge storage.

ESTIMATING PUMPING FREQUENCY

To calculate the time it will take to fill the available storage volume, the amount of solids in the wastewater, the trapping efficiency of the

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Note.—Discussion open until July 1, 1984. To extend the closing date one month, a written request must be filed with the ASCE Manager of Technical and Professional Publications. The manuscript for this paper was submitted for review and possible publication on June 22, 1983. This paper is part of the *Journal of Environmental Engineering*, Vol. 110, No. 1, February, 1984. ©ASCE, ISSN 0733-9372/84/0001-0283/$01.00. Paper No. 18538.

tank, and the solids decomposition must be estimated. These values were determined by using results from many septic tank studies reported by the EPA (3). Comparing the solids content of septic tank influent to effluent yielded an expected trapping efficiency of 70%. The expected decomposition in the tank would be a function of the fraction of the total suspended solids that are volatile which was reported as approximately 50%. The solids loading would be the total suspended solids generated per person daily of 0.2 lb/person/day (90 gm/person/day) (1). These values can be used to estimate the amount of sludge retained in the tank.

$$\text{lb solids retained} = \frac{0.2\ \text{lb}}{\text{person}\cdot\text{day}} \times 50\%\ \text{digestion} \times 70\%\ \text{trap eff.}$$

$$= \frac{0.07\ \text{lb}}{\text{person}\cdot\text{day}} \qquad (2)$$

This dry weight of solids was converted to a volume to estimate pumping frequency. Although considerable data are available on septage characteristics, little are reported on the physical characteristics of this sludge. Therefore, the assumptions were made that the sludge would be 4% solids and have the density of water.

$$\text{Vol. of sludge} = \frac{0.07\ \text{lb}}{\text{person}\cdot\text{day}} \times \frac{\text{gal}}{8.4\ \text{lb}} \times \frac{1}{4\%\ \text{solids}} = \frac{0.21\ \text{gal}}{\text{person}\cdot\text{day}} \qquad (3)$$

By knowing the volume of sludge retained per person daily and the volume available for storage, the necessary pumping frequency can be estimated as follows:

Pumping frequency for 6 people using a 900 gal (3.4 m^3) septic tank

$$\frac{600\ \text{gal of sludge storage}}{6\ \text{people}} \times \frac{\text{person}\cdot\text{day}}{0.21\ \text{gal}} \times \frac{\text{yr}}{365\ \text{days}} = 1.3\ \text{years} \qquad (4)$$

TABLE 1.—Estimated Septic Tank Pumping Frequency for Year-round Residence[a] (In Years)

Tank, in gallons (1)	Number of Persons in Residence 1 (2)	2 (3)	3 (4)	4 (5)	5 (6)	6 (7)	7 (8)	8 (9)	9 (10)	10 (11)	Tank, in cubic meters (12)
500	5.8	2.6	1.5	1.0	0.7	0.4	0.3	0.2	0.1	—	1.9
750	9.1	4.2	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3	2.8
900	11.0	5.2	3.3	2.3	1.7	1.3	1.0	0.8	0.7	0.5	3.4
1,000	12.4	5.9	3.7	2.6	2.0	1.5	1.2	1.0	0.8	0.7	3.8
1,250	15.6	7.5	4.8	3.4	2.6	2.0	1.7	1.4	1.2	1.0	4.7
1,500	18.9	9.1	5.9	4.2	3.3	2.6	2.1	1.8	1.5	1.3	5.7
1,750	22.1	10.7	6.9	5.0	3.9	3.1	2.6	2.2	1.9	1.6	6.6
2,000	25.4	12.4	8.0	5.9	4.5	3.7	3.1	2.6	2.2	2.0	7.6
2,250	28.6	14.0	9.1	6.7	5.2	4.2	3.5	3.0	2.6	2.3	8.5
2,500	31.9	15.6	10.2	7.5	5.9	4.8	4.0	4.0	3.0	2.6	9.5

[a] More frequent pumping is needed if garbage disposal is used.

This value can be calculated for any household and septic tank size.

$$P = \frac{0.0228C}{Lned}(V - Qnt) \qquad (5)$$

in which P = pumping frequency, in years; C = percent solids in sludge; e = trap efficiency; d = fraction of solids digested; n = number of persons; L = per capita loading rate, in pounds per person daily; V = tank volume, in gallons; Q = volumetric loading, in gallons per person daily; and t = liquid detention time, in days.

Table 1 presents the pumping frequency for $C = 4\%$, $L = 0.2$ lb/person·day, $e = 70\%$, $d = 50\%$, $Q = 50$ gal/person·day, and $t = 1$ day, for a number of septic tank and household sizes.

Summary and Conclusions

Based on available data, the frequency of septic tank pumping can be estimated. To increase the reliability of this estimate, better information is needed on the characteristics of the sludge retained in the tank. These pumping frequency calculations are useful to the homeowner for establishing a reasonable septic tank maintenance schedule, to public management authorities in planning their maintenance program, and to regulatory agencies in setting rational rules and regulations for septic tank sizing and design.

Acknowledgments

Contribution from the Department of Agricultural Engineering in cooperation with the Agricultural Experiment Station, The Pennsylvania State University, University Park, Pa. Published with the approval of the Director of the Pennsylvania Agricultural Experiment Station as Journal Series No. 6697.

Appendix.—References

1. Clark, J. W., Viessman, W., and Hammer, M. J., *Water Supply and Pollution Control*, The Haddon Craftsmen, Inc., Scranton, Pa., 1971.
2. Laak, R., "Multichamber Septic Tanks," *Journal of the Environmental Engineering Division*, ASCE, Vol. 106, No. EE3, Proceedings Paper 15472, June, 1980, pp. 539–546.
3. Onsite Wastewater Treatment and Disposal Systems—Design Manual, U.S. Environmental Protection Agency EPA-625/1-80-012, Office of Research and Development, Cincinnati, Ohio, Oct., 1980.

LAKE MANAGEMENT PLAN
WORKSHEETS

WORKSHEET: LAKE MANAGEMENT ASSESSMENT

Lake /Pond Name:
Region:
Investigator:
Date:

Approximately what percentage of the shoreline is owned by DEM?

Approximately what percentage of the surface watershed is owned by DEM?

What types of use occur within the watershed or groundwater drainage area to your lake (s):

Are there any unique resources, such as rare species habitat or historic and archaeological resources, which are associated with the lake?

What lake restoration techniques have been applied in the past in your lake (such as drawdown, chemical applications, etc.):

WORKSHEET: LAKE MANAGEMENT ASSESSMENT
(CONTINUED)

Lake /Pond Name:
Region:
Investigator:

What watershed management controls are in place to limit land development impacts upon lake water quality? (please check)

A. DEM Controls
  1) Site Design
    a. Placement of parking lots away from lakeshore ______
    b. No direct discharge of parking lot storm runoff to lake or its tributaries ______
    c. Natural vegetated land buffer along lake ______
    d. Cluster/open space planning ______
    e. Limit chemical applications to lawn areas adjacent to shore ______
    f. Shoreline protection ______

  2) Septic System Siting
    a. Set back septic systems from lakes to limit bacterial or viral, and phosphorus loading ______
    b. Wastewater performance standards ______
    c. Alternative systems (composting toilets, treatment plants) ______

  2) Construction Controls
    a. Sedimentation and erosion controls are in place during construction ______

  3) Use Controls
    a. No motor boats ______
    b. No swimming ______
    c. Limit off-road vehicles ______
    d. Forestry erosion controls ______

WORKSHEET: LAKE MANAGEMENT ASSESSMENT
(CONTINUED)

Lake /Pond Name:
Region:
Investigator:

B. Community Controls:
  1) Zoning Controls
    a. Watershed management overlay district ______
    b. Prohibition or special permit for potentially hazardous uses ______
    c. Site plan review ______
    d. Undisturbed land buffers along the lake/pond and its tributaries ______
    e. Performance standards ______
    f. Transfer of development rights ______
    d. Cluster development ______

  2) Subdivision Controls
    a. No direct stormwater discharge to lake ______
    b. Environmental impact assessment required ______
    c. Performance standards ______

  3) Board of Health Regulations
    a. No underground fuel storage tanks ______
    b. Septic system design standards ______
    c. Adopt larger septic system setbacks from the lake edge than is specified in Title 5. ______
    d. Nutrient loading limitations ______
    e. Viral and bacterial loading limitations
    f. Phosphate detergent ban ______

  4) Wetland Regulations
    a. Buffer zone restrictions ______
    b. Limitation on surface water discharges to wetlands ______
    c. Erosion and sedimentation Controls ______
    d. Restrictions on Pesticides and Fertilizers ______

C. Land Acquisitions
  1) Purchase of Conservation Land ______
    a. Acquisition of historic sites ______
    b. Acquisition of Rare species habitat ______
    c. Acquisition of shoreline areas ______
    d. Other ______________________________ ______

D. Legislative Actions
  Describe: ______________________________ ______

WORKSHEET: IN-LAKE MANAGEMENT PLAN

Lake /Pond Name:
Region:
Investigator:
Date:

Indicate which in-lake management methods will be used:

	Attempt	Completed
1) Physical Techniques		
a. Benthic screening	______	______
b. Lake level drawdown	______	______
c. Dredging	______	______
d. Harvesting	______	______
e. Hydroraking	______	______
f. Aeration	______	______
g. Hypolimnion Aeration	______	______
h. Hypolimnetic Withdrawl	______	______
i. Sediment Oxidation	______	______
j. Dilution and flushing	______	______
k. Artificial circulation	______	______
2) Biological Techniques		
a. Foodchain manipulation	______	______
3) Chemical Techniques		
a. Herbicides and algicides	______	______
b. Alum	______	______
c. Dye	______	______

Indicate which uses will be allowed and where (sketch):

WORKSHEET: WATERSHED MANAGEMENT PLAN

Lake /Pond Name:
Region:
Investigator:
Date:

Indicate the watershed management methods which will be conducted by DEM:

	Attempt	Completed
1) Site Design		
a. Placement of parking lots away from lakeshore	_____	_____
b. No direct discharge of parking lot storm runoff to lake or its tributaries	_____	_____
c. Natural vegetated land buffer along lake	_____	_____
d. Cluster/open space planning	_____	_____
e. Limit chemical applications to lawn areas adjacent to shore	_____	_____
f. Shoreline protection	_____	_____
2) Septic System Siting		
a. Set back septic systems from lakes to limit bacterial or viral, and phosphorus loading	_____	_____
b. Wastewater performance standards	_____	_____
c. Alternative systems	_____	_____
2) Construction Controls		
a. Sedimentation and erosion controls are in place during construction	_____	_____
3) Use Controls		
a. No motor boats	_____	_____
b. No swimming	_____	_____
c. Limit off-road vehicles	_____	_____
d. Forestry erosion controls	_____	_____

WORKSHEET: WATERSHED MANAGEMENT PLAN
(CONTINUED)

Lake /Pond Name:
Region:
Investigator:

Indicate what watershed management regulations the DEM will assist local communities in adopting:

	To assist	Adopted
1) Zoning Controls		
a. Watershed management overlay district		
b. Prohibition or special permit for potentially hazardous uses		
c. Site plan review		
d. Undisturbed land buffers along the lake/pond and its tributaries		
e. Performance standards		
f. Transfer of development rights		
d. Cluster development		
2) Subdivision Controls		
a. No direct stormwater discharge to lake		
b. Environmental impact assessment required		
c. Performance standards		
3) Board of Health Regulations		
a. No underground fuel storage tanks		
b. Septic system design standards		
c. Adopt larger septic system setbacks from the lake edge than is specified in Title 5.		
d. Nutrient loading limitations		
e. Viral and bacterial loading limitations		
f. Phosphate detergent ban		
4) Wetland Regulations		
a. Buffer zone restrictions		
b. Limitation on surface water discharges to wetlands		
c. Erosion and sedimentation Controls		
d. Restrictions on Pesticides and Fertilizers		

Indicate what land acquisitions will be pursued:

	To do	Obtained
1) Purchase of Conservation Land		
a. Acquisition of historic sites		
b. Acquisition of Rare species habitat		
c. Acquisition of shoreline areas		
d. Other ______________________________		

SECTION 5.

ENVIRONMENTAL PERMITTING REQUIREMENTS

ENVIRONMENTAL PERMITTING REQUIREMENTS

See page 4-75 through 4-107 for a review of permitting requirements.

All work in waterbodies or in their tributaries, outlets or bordering wetlands is subject to regulatory review. The scope of a proposed project defines the regulatory requirements that must be complied with. There are three regulatory levels: local, state and federal. Some environmental laws originate ion the state, but are locally implemented. In many cases, issuance of some permits is dependent upon successful review and issuance of other related permits. The more complicated a proposed project is, the more complicated and intricate the regulatory flow chart becomes. The following is a list of key permits. Tables 4.4 through 4.6 from the coursebook summarize each of the regulations described in this section.

PERMITS REQUIRED FOR TYPICAL RESTORATION AND MAINTENANCE PLANS

Local Permits

1. Conservation Commissions

Jurisdiction: Any work in, over or adjacent to waterbodies, wetlands, rivers, streams within municipality.

Application Forms: Request for Determination of Applicability: to identify jurisdiction and regulatory requirements.

Notice of Intent: Full application form for complete project description, analysis of impacts, discussion of mitigating measures.

Permit: Determination of Applicability
Order of Conditions

2. Boards of Health

Jurisdiction: Public Health, Safety and Welfare relative to sewage disposal, bathing beaches.

Application Forms: Established locally.

Permit: Established locally.

3. Planning Boards, Boards of Selectmen, Zoning Boards of Appeal

Jurisdiction: Local overlay districts relative to ponds/lakes remediation or management.

Application Forms: Established locally.

Permit: Established locally.

State Permits

The following permits are summarized in Table 4.1 from the coursebook and are described in greater detail in this section.

1. Department of Environmental Protection

Division of Wetlands and Waterways - Wetlands Protection Program

This program has been described fully in the Local Regulation Section, as local Conservation Commissions are responsible for the implementation of the Wetlands Protection Act and the regulations ar 310 CMR 10.00. However, upon appeal, the DEP becomes the issuing authority.

1990 Wetland Program Policy

The DEP is currently in the process of developing a wetlands program policy regarding lake drawdown which will recommend that Conservation Commissions request an applicant to compile a minimum amount of information to assess whether plant species composition will be successfully effected by the drawdown. This information may include the following:

- assess drawdown in relation to the interests in the Act including
- water supply and water quality impacts
- rare species
- refill capacity
- bathymetry of lake
- dam structure
- ground water
- down stream impacts
- wildlife habitat

Mr. Gary Gonyea in the Boston DEP office is preparing the policy.

Further Information:

Regional DEP Office or
Boston Office: Department of
Environmental Protection
Div. of Wetlands and Waterways
One Winter Street
Boston, MA 02018
(617) 292-5695

Division of Wetlands and Waterways - Wetlands Restriction Program

Jurisdiction: The purpose of the Wetlands Restriction Program is to map all the state's wetlands and select the most important wetlands for deed restrictions which prohibit activities that would impair their functions. A list of communities having wetlands restrictions is included. Depending on an individual deed restriction, lake management and remediation work may not be allowed. Typically, destruction of natural vegetation, alteration of existing patterns of flow, alteration of natural contours, discharge of pesticides and draining and dredging have been prohibited.

To place a restriction on a wetland area, public hearings and site visits must be held.

Application: Notice of Intent, per 310 CMR 10.00.

Permit: Order of Conditions, per 310 CMR 10.00.

Further Information:
Scott Boots, Program Coordinator
Wetlands Restriction Program
Division of Wetlands & Waterways
One Winter Street
Boston, MA 02108

Division of Wetlands and Waterways - Waterways Regulation

Jurisdiction: (1) all waterways, including all flowed tidelands and all submerged lands lying below the high water mark of:

- (a) Great Ponds;
- (b) the Connecticut River;
- (c) the section of the Westfield River in the Towns of West Springfield and Agawam lying between the confluence of said river with the Connecticut River and the bridge across said river at Suffield Street in said Town of Agawam;

(d) the non-tidal river or stream on which public funds have been expended for stream clearance, channel improvement, or any form of flood control or prevention work, either upstream or downstream within the river basin, except for any portion of any such river or stream which is not normally navigable during any season, by any vessel including canoe, kayak, raft, or rowboat; the Department may publish, after opportunity for public review and comment, a list of navigable streams and rivers; and

(2) all filled tidelands, except for landlocked tidelands, and all filled lands lying below the natural high water mark of Great Ponds (310 CMR 9.04).

Application Form: Application Form 1; Dredging Addendum Application Form 2; Municipal Zoning Certification Application Form 3; and Municipal Planning Board Notification Application Form 4. To identify whether a project is subject to the regulations, one may submit a Request for Jurisdictional Determination (informal) or a formal Determination of Applicability (310 CMR 9.05). All forms are currently under revision.

Permit: Chapter 91 Permit or Chapter 91 License

Further Information: John Simpson (or ask receptionist for the staff person responsible for community in which project is proposed)
Division of Wetlands and Waterways
Waterways Regulation Program
One Winter Street
Boston, MA 02108
(617) 292-5695

Division of Water Pollution Control - Water Quality Certification

Jurisdiction: Administration of water quality certification of dredged and dredged material disposal and filling. The Water Quality Certification regulations are promulgated in order to establish procedures, criteria and standards for the uniform and coordinated administration of water quality criteria of dredging and dredged material disposal and filling projects in waters of the Commonwealth (314 CMR 9.01).

Application Form: Two parts: "Standard Application Form" and a "Supplemental Information Form" (314 CMR 9.90).

Permit: Water Quality Certification

Further Information: Division of Water Pollution Control
One Winter Street
Boston, MA 02108
(617) 292-5673

Division of Water Pollution Control - License to Apply Chemicals

Jurisdiction: Application of chemicals to water body for weed control

Application Form: Application for License to Apply Chemicals for Control of Nuisance Aquatic Vegetation (copy enclosed)

Permit: License to Apply Chemicals for Control of Nuisance Aquatic Vegetation

Further Information: Division of Water Pollution Control
Technical Services Branch
Lyman School
Westborough, MA 01581
(508) 792-7470

Division of Solid Waste Management

Jurisdiction: Disposal of Dredged Material in approved landfill.

Application Form: If the dredge spoils are not deemed acceptable for sale or use as a daily landfill cover, soil conditioner or embankment fill, Request for Determination whether dredged material or other lake remediation solid waste is a special waste per 310 CMR 19.061.

Permit: Issuance of written determination.

Further Information: Division of Solid Waste Management
One Winter Street
Boston, MA 02108
(617) 590-5961

2. Department of Fisheries, Wildlife and Environmental Law Enforcement

Division of Fisheries and Wildlife

Jurisdiction: Review of drawdown activities and impact on fisheries and wildlife interests.

Application Form: Written Notification to Division, coordination with local Conservation Commission is recommended.

Permit: Conditions recommended by Division to local Conservation Commission

Further Information: Division of Fisheries and Wildlife
Westborough, MA
(508) 366-4470

3. Massachusetts Coastal Zone Management

Jurisdiction: Compliance of projects requiring federal permits to coastal zone regulatory and non-regulatory policies in the Massachusetts coastal zone. The regulations are promulgated to comply with the requirements of the Federal Coastal Zone Management Act of 1972, as amended. Any lake remediation or management project which requires a permit from the U.S. Army Corps of Engineers (e.g. filling in wetlands, dredging) or the U. S. Environmental Protection Agency (e.g. NPDES permit), when conducted in the coastal zone will require a CZM consistency review.

Application Form: Consistency Certification, federal and state permit applications (as appropriate), final decision of the MEPA process (as appropriate), other information, as deemed necessary. (301 CMR 21.10)

Permit: Concurrence with Consistency Certification, Consistency Certification Determination.

Further Information: Office of Coastal Zone Management
100 Cambridge Street
Boston, MA 02202
(617)727-9530

4. Massachusetts Historical Commission

Jurisdiction: Elimination, minimization or mitigation of impact to properties listed in the State Register of Historic Places. This may be applicable to lakes management and remediation projects should dredging or drawdown significantly impact an archaeological or historic site. The regulations establish a standardized procedure to protect the public's interest by directing state bodies to notify the Massachusetts Historical Commission as early as possible in the planning process of any project either undertaken by the state body or prior to the state body's funding or licensing a private project.

Application Form: Project Notification Form or Environmental Notification Form, depending upon whether MEPA is triggered by the project.

Permit:	Determination of Adverse Effect: either No Effect, Determination of No Adverse Effect or Determination of Adverse Effect. (95- CMR 71.07)
Further Information:	Massachusetts Historical Commission 80 Boylston Street Suite 310 Boston, MA 02116 (617) 727-8470

5. Department of Environmental Management

Office of Dam Safety

Jurisdiction:	Safety and inspection of dams greater than 6 feet in height or which can store 15 acre-feet of water or which, upon breach, could endanger property or public safety.

The definition of dam is established at 302 CMR 10.06:

> "Dam shall mean any artificial barrier, including appurtenant works, which impounds or diverts water, and which is (1) twenty-five feet or more in height as defined herein and (2) has an impounding capacity at maximum water storage elevation of fifty acre-feet or more. Dam shall also mean any other artificial barrier, including appurtenant works, the breaching of which could endanger property or safety, as determined by the Commissioner, and is greater than six (6) feet in height or impounds more than fifteen (15) acre feet of water; or any structure classified as a roll dam."

Hazard Potential is defined as "the potential for causing property damage or loss of human life in the event of failure or improper operation of a dam."

Application Form:	Dam Registration Forms, Notice of Intent to determine whether Chapter 253 Permit is required.
Permit:	Chapter 253 Permit to Construct, Repair, or Remove a Dam ("Chapter 253 Permit"), Certificate of Compliance or Non-Compliance

Further Information: Office of Dam Safety
Department of Environmental Safety
100 Cambridge Street
Boston, MA 02202
(617) 727-3174

6. Massachusetts Environmental Policy Act (MEPA)

Jurisdiction: Overall environmental review of projects requiring state permits, funding or other state action. The Massachusetts Environmental Policy Act regulations provide a uniform system for compliance with the Massachusetts Environmental Policy Act, M.G.L. Chapter 30, sections 61 through 62H. MEPA applies to the activities of all agencies of the Commonwealth, to all activities carried out with financial assistance from agencies, and to all activities which require permits granted by agencies. The regulations establish thresholds, a procedure, and a timetable for a two-level review process, which generally includes filing of an Environmental Notification Form (ENF) and an Environmental Impact Report (EIR).

An ENF and EIR is an informational planning document which is intended to inform project proponents, public decision makers and the general public of the environmental effects of proposed activities, to enable environmental damages and benefits to be fully disclosed and considered. (301 CMR 11.01)

For lake and pond remediation and management work, the MEPA process may be triggered in several ways: if state funds are being used for the proposed activities, if an Order of Conditions is appealed to the Department of Environmental Protection and more than a specified area of wetland resource area is being altered (310 CMR 11.26, filing of an ENF is required) or if more than 10 acres of a wetland resource area is proposed to be altered (301 CMR 11.25, filing of an EIR is required). Additionally, any agency action necessitating physical alteration in an Area of Critical Environmental Concern (ACEC) requires filing of an ENF (301 CMR 11.15).

Application Form: Environmental Notification Form (ENF), 10 page form with questions asking for project description, description of site environment and regional environment, an analysis of potential impacts and mitigating measures and proposed project benefits. (301 CMR 11.28)

Further Information: Massachusetts Environmental Policy Act Unit
Executive Office of Environmental Affairs
100 Cambridge Street, 20th floor
Boston, MA 02202
(617) 727-5830

7. Department of Food and Agriculture

Pesticide Bureau

Jurisdiction: The purpose of the Pesticide Bureau regulations is to establish the standards, requirements and procedures for the certification and licensing of pesticide applicators, including specific requirements for aquatic pest control. No person shall use a pesticide that has been classified by the Pesticide Board as being for restricted or state limited use unless he is an appropriately certified private or commercial applicator. (333 CMR 10.03) All certifications and licenses shall be for a period not to exceed one year. Categories of Commercial Applicators are established at 333 CMR 10.04.

Application Form: Competence in the use and handling of pesticides shall be determined on the basis of written examinations and performance testing. (333 CMR 10.05) In the case of aquatic pest control, the applicators shall demonstrate practical knowledge of the principals of limited area treatments and the potential for adverse effects on fish, birds, beneficial insects, and other non-target organisms that may be present. (333 CMR 10.05 (2) (e)) Procedures are established at 333 CMR 10.09.

Further Information: Pesticide Bureau
Dept. of Food & Agriculture
100 Cambridge Street
Boston, MA 02202
(617) 727-7712

8. Metropolitan District Commission

Jurisdiction: Use of reservoirs, roadways, driveways, bridges, dams, and land within watershed reservations under the care and control of the Metropolitan District Commission are regulated. The regulations establish general regulations relative to use of land within watershed reservations. (350 CMR 8.01) All acts which pollute the water supply are prohibited. No person shall wade or swim unless authorized. Similarly, picnicking, cooking, ball playing, etc. is only allowed where specifically posted or designated. Special regulations for Quabbin Reservoir are established at 350 CMR 8.01 (2) and specify fishing and boating regulations.

9. Department of Environmental Protection

Jurisdiction: The Department of Environmental Protection has established regulations to promote the public health and general welfare by ensuring that public water systems in Massachusetts provide safe drinking water to its users. The regulations set forth standards and requirements of general application and future effect.

10. Other State Permits That May Apply For Major Lake Remediation Projects

DEP, Division of Water Pollution Control - National Pollutant Discharge Elimination System (NPDES) Permit Program

Jurisdiction: Point Source discharges to surface and ground waters, proper wastewater treatment. This would apply if a treatment plant were proposed in association with lake remediation or management or if a point source discharge of stormwater from certain types of land use were proposed. This permit is issued jointly by the EPA and the Division of Water Pollution Control. A permit is submitted to the EPA and reviewed jointly by both agencies.

Application Forms: Application for Permit to Discharge to Waters of the Commonwealth, Application to Discharge to Ground and Application for Permit for Sewer System Extension or Connection.

Permits: Permit for each of the above.

Further Information: Division of Water Pollution Control
One Winter Street
Boston, MA 02108
(617) 292-5673

Federal Permits

1. U.S. Army Corps Of Engineers, Section 404 Permit To Dredge And Fill In Waters Of The United States

Jurisdiction: Any activity which results in the dredge and fill in waters of the United States, including wetlands and waterways.

Application Form: Standard Application Form 33 CFR 325, in addition to a Notice of Intent under the Massachusetts Wetlands Protection Act and regulations at 310 CMR 10.00.

Permit: U.S. Army Corps Permit

Further Information: Regulatory Branch
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149
(617) 647-8156
(800) 362-4367

2. Environmental Protection Agency - National Pollutant Discharge Elimination System (NPDES) Permit Program

Jurisdiction: Discharge of a point source discharge in waters of the United States. This permit is issued jointly by the EPA and the Division of Water Pollution Control. A permit is submitted to the EPA and reviewed jointly by both agencies.

Application: NPDES Permit Application

Permit: NPDES Permit

Further Information: Olga Vergara WCP-2109
Environmental Protection Agency
J.F.K. Federal Building
Boston, MA 02203
(617) 565-3529

TABLE 4.4

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

LOCAL

	CONSERVATION COMMISSION	BOARD OF HEALTH
Purpose	•Protection of water resources •Avoid or minimize impact to wetland functions	•Public health, safety & welfare •Accredation of bathing beaches
Statute	•MGL C.131, S.40 •Local bylaw or ordinance	•State Environmental Code: Title 5 MGL C.111, S.17 •State Sanitary Code, Chapter VII MGL C.111, S.127A
Regulations	•310 CMR 10.00 •Local regulations	•310 CMR 15.00 •105 CMR 445.00
Geographic Jurisdiction	•Activity in waterbodies, adjacent wetlands (as defined in the regulation), or 100 foot buffer zone	•Statewide subsurface discharges of less than 15,000 gpd to ground (i.e., septic systems) •Statewide water bodies
Permit	•Determination of Applicability •Order of Conditions	•Subsurface Sewage Discharge Permit •Accredited Bathing Beach License
Application Form	•Request for Determination of Applicability •Notice of Intent	•Town specific •Application for license to operate an accredited bathing beach
Fees	•Established at 801 CMR 4.00	•Determined locally

This table is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

FEDERAL

ARMY CORPS OF ENGINEERS	ENVIRONMENTAL PROTECTION AGENCY
Purpose	**Purpose**
•General environmental concerns •Wetlands •Fisheries •Wildlife •Flood hazards •Navigation •Recreation •Water quality •Economics •Aesthetics •Land use	Protection of: •Water quality •Wetlands
Statute	**Statute**
•Rivers & Harbors Act •Clean Water Act of 1977 •Marine Sanctuaries Act	•Clean Water Act S.404 (b)(1)
Regulations	**Regulations**
•33 CFR Parts 320-330	•40 CFR Parts 230
Geographic Jurisdiction	**Geographic Jurisdiction**
•Navigable waters & wetlands	•Navigable waters & wetlands
Permit	**Permit**
•Section 9 & 10/structures •Section 404/fill •Section 103/transport	•Findings of Compliance
Application Form	**Application Form**
•Notice of Intent (same as wetlands Protection Program) or standard application	•Factual Determination
Fees	**Fees**
•None	•None

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

STATE

	MASSACHUSETTS ENVIRONMENTAL POLICY ACT UNIT	DEPARTMENT OF ENVIRONMENTAL PROTECTION DIVISION OF WETLANDS AND WATERWAYS	
		WETLANDS PROTECTION PROGRAM	WETLANDS RESTRICTION PROGRAM
Purpose	•Overall environmental impact review & impact minimization •Identification of issues, centralized information gathering	•Protection of water resources •Avoid or minimize impact to wetland functions	•Map all state wetlands at 1:5000 •Place deed restriction prohibiting certain activities
Statute	•MGL C30, S.61-62H	•MGL C131, S.40	•MGL C130, S.105 (coastal) •MGL C131, S.40A (inland)
Regulations	301 CMR 11.00	310 CMR 10.00	302 CMR 4.00 & 6.00
Geographic Jurisdiction	Statewide: •Requires a state action or permit •Threshold exceeded (as listed in 301 CMR 11.00) •Requires expenditure of state funds •An Area of Critical Environmental Concern (ACEC)	•Activity in waterbodies, adjacent wetlands (as defined in the regulation), or 100 foot buffer	Statewide: Wetlands •See list of cities & towns with Orders of Restriction
Permit	•Certificate of the Secretary of the Executive Office of Environmental Affairs	•Superseding (final) Order of Conditions if local order appealed	•Order of Conditions •Deed Restriction, Order of Restriction
Application Form	•Environmental Notification Form •Environmental Impact Report	•Notice of Intent	•Notice of Intent •Restriction Process
Fees	•none	•801 CMR 4.02	•801 CMR 4.02

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

STATE

DEPARTMENT OF ENVIRONMENTAL PROTECTION

	DIV. OF WETLANDS & WATERWAYS WATERWAYS REGULATION PROGRAM	DIVISION OF WATER POLLUTION CONTROL	DIVISION OF SOLID WASTE
Purpose	•Protection of public rights of fishing, fowling & navigation through - navigation safety, structural soundness, promote public access, littoral property rights protection, natural resource protection, public facilities operation protection	Administration of •dredging material disposal •wetland filling •regulation of discharges of pollutants to surface and ground waters	•Proper disposal of dredged materials
Statute	•MGL C.91	MGL C.111, S5E	•MGL C.21A, S2&8 •MGL C.111, S150A
Regulations	•310 CMR 9.00	•314 CMR 9.00 •314 CMR 4.00	•310 CMR 19.00
Geographic Jurisdiction	•Filled tidelands •Mean high water line to 3 miles seaward •Rivers •Great ponds •Waterways that are fish runs •Waterways which have received public funds	•Wetlands •Waterbodies	•Landfill or disposal site accepting dredge materials
Permit	•Chapter 91 Waterways License •Determination of Applicability	•Water Quality Certificate •License to apply chemicals	•Request for Determination whether solid waste is a special waste per 310 CMR 19.061
Application Form	•Standard application •Request for Determination of of Applicability •Request for jurisdictional determination (informal)	•Standard application •Applicaton to apply chemicals	•Issuance of Written Determination
Fees	•310 CMR 9.16 (no fee for public agencies, including DEM)	•None at present	•None at present

TABLE 4.4 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

		STATE	
		DFWELE	DEPT. OF ENVIRONMENTAL MGMT
	MASSACHUSETTS COASTAL ZONE MANAGEMENT	DIVISION OF FISHERIES AND WILDLIFE	OFFICE OF DAM SAFETY
Purpose	•All activities affecting coastal resources as stated in 27 MCZM Program Policies	1. Impose conditions regarding fisheries & wildlife interests 2. Protection of rare and endangered species	•Oversee safety of dams
Statute	•Federal CZM Act	1. MGL Chapter 132, S.42 & 48 2. MGL Chapter 131, S.40	•MGL C.253, S.44-50
Regulations	•301 CMR 21.00 •301 CMR 20.00 •15 CFR Part 930	1. None 2. 310 CMR 10.37 & 10.59, 321 CMR 8.00	302 CMR 10.00
Geographic Jurisdiction	•Designated coastal zone •All activities directly affecting coastal zone & exceeding thresholds listed in MEPA regulations	•Statewide	•Dams greater than 6 feet in height or which can store 15 AF of water or which upon breach could endanger property or public safety
Permit	•Federal Consistency Concurrence	1. Coordination with local Conservation Commission 2. Order of Conditions per 310 CMR 10.00	•Chapter 253 Permit •Certificate of Compliance or Non-compliance
Application Form	•Consistency Certificate & Federal Permit Application	1. Written notification 2. Appendix A to NOI	•Notice of Intent •Dam Registration Form
Fees	•None at present	1. None 2. 801 CMR 4.02	•None at present

TABLE 44 (continued)

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR IN-LAKE MANAGEMENT AND RESTORATION

STATE

		DEPT. OF FOOD & AGRICULTURE	
	MASSACHUSETTS HISTORICAL COMMISSION	MASSACHUSETTS PESTICIDE BUREAU	METROPOLITAN DISTRICT COMMISSION
Purpose	•Preserving historic or archaeological properties and resources	•Certification & licensing of applicators •Registration of pesticides & herbicides	•Prevention of pollution in MDC waters
Statute	•MGL C.9, S.26-27C	•MGL C.132B, S.6A&10	•MGL C.92, S.10-19
Regulations	•950 CMR 71.00	•333 CMR 2.00 & 10.00	•310 CMR 23.00 •350 CMR 8.00, 9.00
Geographic Jurisdiction	•Statewide	•Statewide application of pesticides and herbicides	•MDC Water per •310 CMR 23.01
Permit	•Determination of Effect	•Certification & License Document	•Written permit, legislation or special regulation
Application Form	•Project Notification Form or Environmental Notification Form	•Examination, application for certification or licensing	•Written notification
Fees	•None	•$25.00 - $50.00	•None

TABLE 4.5

MASSACHUSETTS REGULATORY REVIEW AND PERMITTING PROCESS FOR WATERSHED MANAGEMENT TECHNIQUES

LOCAL	STATE	FEDERAL
	DEPARTMENT OF ENVIRONMENTAL PROTECTION	
PLANNING BOARD, ZONING BOARD	DIVISION OF WATER POLLUTION	ENVIRONMENTAL PROTECTION AGENCY
Purpose •Land planning and development	**Purpose** •Surface and ground water discharges •Proper wastewater treatment	**Purpose** •Protection of water quality
Statute •MGL 40A, 41	**Statute** •Federal Clean Water Act •State MGL C.21, S.43	**Statute** •Clean Water Act Section 301 & 402
Regulations •Local •Zoning Bylaws •Zoning Map •Master Plan •Subdivision Control	**Regulations** •314 CMR 2.00, 3.00 & 5.00, 7.00	**Regulations** •40 CFR Parts 122-125
Geographic Jurisdiction •Municipality	**Geographic Jurisdiction** •Waters receiving discharges	**Geographic Jurisdiction** •Waters receiving discharges
Permit •Zoning approvals •Subdivision approval •Approval not required	**Permit** •Permit for discharge proposed	**Permit** •Natural Pollutant Discharge Elimination System (NPDES)
Application Form •Specified in Zoning Bylaws •Specified in Subdivision Rules and Regulations	**Application Form** •Application for Permit to Discharge to Waters of the Commonwealth •Application for Permit to Discharge to Ground •Application for Permit for Sewer System Extension or Connection	**Application Form** •NPDES
Fees •Established locally	**Fees** •Established by Executive Office of Administration and Finance	**Fees** •None

Note: All regulatory processes identified in Table 4.4 apply for watershed management as well. For ease in use of these tables, the regulations presented in Table 4.4 are not reproduced in Table 4.5.

TABLE 4.6 Activities and Potential Permits

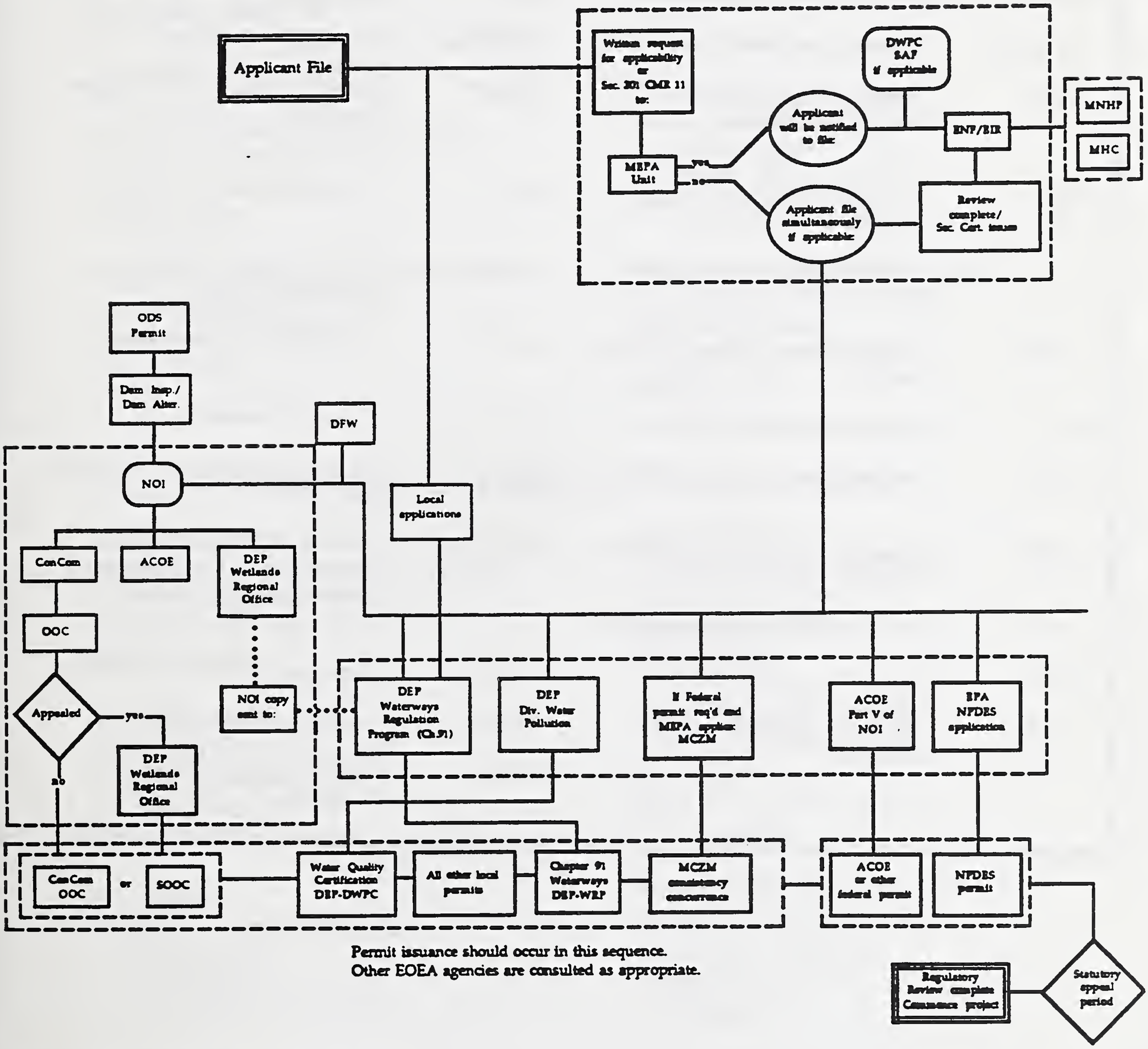
						F&W			F&A					
	WPA	WRP	C.91	DWPC	Sol. Wst.	R&E/Exot/DD	ODS	MHC	Pest. Bur.	MDC	DEP	MEPA	ACOE	EPA
PHYSICAL TECHNIQUES														
Benthic Screening	X	X								X	X	X		
Lake Level Drawdown	X	X	X	X		X X	X			X	X	X	X	
Dredging	X	X	X	X	X	X X		X		X	X	X	X	X
Harvesting	X	X				X				X	X	X		
Hydroraking	X	X	X	X		X				X	X	X		
Aeration	X	X	X	X						X	X	X		
Hypolimnetic Withdrawal	X	X	X	X			X			X	X	X	X	X
Sediment Oxidation	X	X	X	X						X	X	X	X	X
Dilution and Flushing	X	X	X	X						X	X	X		
Artificial Circulation	X	X	X	X						X	X	X	X	X
BIOLOGICAL TECHNIQUES														
Grass Carp	X	X				X X				X	X	X	X	
Pathogens	X	X				X				X	X	X	X	
Insect Pests	X	X				X				X	X	X	X	
Food Chain Manipulation	X	X				X				X	X	X	X	
CHEMICAL TECHNIQUES														
Herbicides & Algicides	X	X				X			X	X	X	X		
Alum	X	X				X				X	X	X		
Dye	X	X				X				X	X	X		
OTHER														

This table is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

FIGURE 4.16

Massachusetts Permit Processing Flow Chart

Flow chart of filing and processing sequence for non-controversial proposing activities relative to lakes management and adjacent wetlands


Applicant File
Written request for applicability or Sec. 301 CMR 11 to:
MEPA Unit
yes
no
Applicant will be notified to file
Applicant file simultaneously if applicable
DWPC SAF if applicable
ENF/EIR
Review complete/ Sec. Cert. issues
MNHP
MHC
ODS Permit
Dam Insp./ Dam Alter.
DFW
NOI
Local applications
ConCom
ACOE
DEP Wetlands Regional Office
OOC
Appealed
yes
no
DEP Wetlands Regional Office
NOI copy sent to:
DEP Waterways Regulation Program (Ch.91)
DEP Div. Water Pollution
If Federal permit req'd and MEPA applies: MCZM
ACOE Part V of NOI
EPA NPDES application
ConCom OOC
or
SOOC
Water Quality Certification DEP-DWPC
All other local permits
Chapter 91 Waterways DEP-WRP
MCZM consistency concurrence
ACOE or other federal permit
NPDES permit
Regulatory Review complete Commence project
Statutory appeal period

Permit issuance should occur in this sequence.
Other EOEA agencies are consulted as appropriate.

Adapted from Massachusetts Coastal Permit Processing Flow Chart, Technical Bulletin No. 4, June 1989, Coastal Brief, Jim O'Connell, Author.

Key to Acronyms on following page

This figure is taken from the coursebook prepared for this course. Please refer to the coursebook for further explanation.

FIGURE 4.16 (continued)

Massachusetts Permit Processing Flow Chart

Key to Acronyms

ACOE	U.S. Army Corps of Engineers	MHC	Massachusetts Historical Program
ConCom	Conservation Commission	MHWL	Mean High Water Line
CZM	Massachusetts Coastal Zone Management Office	MNHP	Massachusetts Natural Heritage Program
DEP	Department of Environmental Protection	NOI	Notice of Intent
DFW	Division of Fisheries and Wildlife	NPDES	National Pollutant Discharge Elimination System
DWPC	DEP - Division of Water Pollution Control	ODS	DEM - Office of Dam Safety
EIR	Environmental Impact Report	OOC	Order of Conditions
ENF	Environmental Notification Form	SAF	Standard Application Form for the DEP - DWPC
EOEA	Executive Office of Environmental Affairs	Sec. Cert.	Certificate of the Secretary of Environmental Affairs regarding completion of MEPA process
EPA	Environmental Protection Agency		
LAC	License to Apply Chemicals	SOOC	Superceding Order of Conditions
MEPA	Massachusetts Environmental Policy Act	WPA	Wetlands Protection Act
		WRP	DEP - Waterways Regulation Program

SOURCES OF FURTHER INFORMATION

List of Regulatory Agencies and Permit Application Forms

Regulatory Agencies

The regional DEQE offices are:

DEQE Northeast Regional Office
5 Commonwealth Avenue
Woburn, MA 01801
(508)935-2160

DEQE Southeastern Regional Office
Lakeville Hospital
Lakeville, MA 02346
(508)947-1231

DEQE Central Regional Office
75 Grove Street
Worcester, MA 01605
(508)792-7650

DEQE Western Regional Office
State House West-4th Floor
436 Dwight Street
Springfield, MA 01103
(413)785-5327

District Office of the Division of Fisheries and Wildlife are as follows:

FIELD HEADQUARTERS:
Division of Fisheries and Wildlife
Field Headquarters
Westborough, MA 01581
(508)366-9181

WESTERN:
Wildlife District Manager
Hubbard Avenue
Pittsfield, MA 01201
(413)447-9789

CENTRAL:
Wildlife District Manager
Temple Street
W. Boylston, MA 01583
(617)835-3607

SOUTHEAST:
Wildlife District Manager
Bournedale Road
Buzzards Bay, MA 02532
(617)759-3406

CONNECTICUT VALLEY:
Wildlife District Manager
East Street
Belchertown, MA 01007
(413)323-7632

NORTHEAST:
Wildlife District Manager
Harris Street, Box 86
Acton, MA 01720
(617)263-4347

LAKE MANAGEMENT PERMITS
WORKSHEETS

WORKSHEET: LAKE MANAGEMENT PERMITTING

Check-off the permits which must be obtained for proposed management plan.

	WPA	WRP	C. 91	DWPC	Sol. Wst.	CZM	F&W R&E/Exot/DD	ODS	MHC	F & A Pest.Bur.	MDC	DEP	MEPA	ACOE	EPA
PHYSICAL TECHNIQUES															
Benthic Screening															
Lake Level Drawdown															
Dredging															
Harvesting															
Hydroraking															
Aeration															
Hypolimnetic Withdrawal															
Sediment Oxidation															
Dilution and Flushing															
Artificial Circulation															
BIOLOGICAL TECHNIQUES															
Grass Carp															
Pathogens															
Insect Pests															
Food Chain Manipulation															
CHEMICAL TECHNIQUES															
Herbicides & Algicides															
Alum															
Dye															
OTHER															

SECTION 6.

POST-TREATMENT MONITORING

POST-TREATMENT MONITORING

Proper post-treatment monitoring will vary greatly with the treatment employed and the results desired. Presumably, the most sought-after improvements will be greater water clarity or lower aquatic plant density. In these cases, Secchi transparency and cover by plants (as percent cover and/or biomass per unit area for each species) are the preferred monitoring parameters. Additional parameters of interest will include phosphorus, nitrogen, dissolved oxygen, pH and characterization of the phytoplankton, fish and invertebrate communities, but managers should be careful not to overextend a limited budget. It is best to select a few parameters which adequately characterize management progress and to monitor these parameters at appropriate intervals.

Monitoring frequency will vary from around once every two weeks for Secchi transparency to once every year or two for the fish community. For most chemical parameters, monthly measurement is adequate, while seasonal measurement is appropriate for plankton. Rooted plant density should be assessed at least annually and preferably twice per year, in late spring and late summer.

The selection of parameters will also be dependent upon the pre-treatment data. Adequate pre-treatment data is essential to a valid before-after comparison, and consistency of methods in each project phase is necessary. If one form of phosphorus was measured before an alum treatment. Other forms may be added for an improved interpretation of results, but the original form cannot be dropped if a valid before-after comparison is to be made.

If reduced loading of a given pollutant is anticipated, flow will need to be monitored to allow an evaluation of changes in loading. Even if the pollutant concentration is assessed only once per month, more frequent flow measurement is desirable. Flows can be highly variable, but it is inexpensive to quantify this variation. Dry and wet weather measurements are necessary.

Where the treatment has a drastic effect on the environment (e.g., dredging, chemical treatment, harvesting), effects should be detectable immediately, but several years may be necessary for the system to reach a new equilibrium, if one is indeed reached. A three-year post treatment monitoring program is advisable in nearly all cases, with some degree of monitoring warranted on an ongoing basis in most cases. What is typically a relatively small monitoring cost is nearly always warranted to protect the investment made through management.

Where the treatment is expected to gradually change the system through reduced pollutant loading (most watershed-based techniques) or biomanipulation (e.g., fish stocking, selective planting), it is critical to allow enough time to make valid statistical comparison. Where slow changes are involved, natural variability (dry years vs. wet years, for instance) may overshadow the change in any given year, necessitating multiple years of monitoring. The human eye rarely detects any change in water clarity below an actual change of 20%, and a statistical test for changes of less than 20% is likely to require tens of data points. As spacing these points too close together in time can destroy the statistical validity of the comparison, several years of data are generally required for a valid assessment.

Not all changes require statistical verification, however. User perceptions or simple photographs are often sufficient to assess project progress. It could take a very expensive monitoring program to assess the effect of fish stocking on fish size structure and angling success. It may be easier and more appropriate to simply interview fishermen before and after stocking to record their impressions and satisfaction level. The level of stocking should be adjusted to meet demand within ecological reason, as opposed to achieving some less tangible size structure goal.

Tailoring a monitoring program to meet the specific needs of a management program can be challenging and at times frustrating. Professional help is advisable, particularly when setting up the program. It is highly desirable to enter a treatment phase with a standardized set of measurements and a framework for comparison which needs only the data to be complete. A proper post-treatment monitoring program will allow charting of progress as well as documentation of goal achievement, and is well worth the investment.